XXXV. ON THE SPREAD OF EPIDEMIC PLAGUE THROUGH DISTRICTS WITH SCATTERED VILLAGES[1].

PART I.

CONTENTS.

I. Introduction.

A. Scope of observations.

B. Districts in which observations were made.

1. Rohtak.
2. Mozuffarnagar.
3. Amritsar.

Analysis of the data obtained.

II. Method of spread of the epidemics in each district as judged from the maps.

A. Rohtak District.

(*a*) Epidemic of 1903—04.
(*b*) ,, ,, 1904—05.
(*c*) ,, ,, 1905—06.
(*d*) ,, ,, 1906—07.

B. Mozuffarnagar District.

(*a*) Epidemic of 1902—03.
(*b*) ,, ,, 1903—04.
(*c*) ,, ,, 1904—05.
(*d*) ,, ,, 1905—06.
(*e*) ,, ,, 1906—07.

C. Amritsar.

(*a*) Epidemic of 1901—02.
(*b*) ,, ,, 1902—03.
(*c*) ,, ,, 1903—04.
(*d*) ,, ,, 1904—05.
(*e*) ,, ,, 1905—06.
(*f*) ,, ,, 1906—07.

D. Summary.

[1] The Committee are indebted to Major Lamb, Director of the Pasteur Institute, Kasauli, for the collection and arrangement of these data which he undertook after he had ceased to be a member of the working Commission in India and had joined the Advisory Committee.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

III. Previous plague history of the villages infected in each epidemic.

IV. Previous plague history of villages infected at the beginning of each epidemic.

A. Rohtak District.

(*a*) Epidemic of 1903—04.
(*b*) ,, ,, 1904—05.
(*c*) ,, ,, 1905—06.
(*d*) ,, ,, 1906—07.

B. Mozuffarnagar District.

(*a*) Epidemic of 1903—04.
(*b*) ,, ,, 1904—05.
(*c*) ,, ,, 1905—06.
(*d*) ,, ,, 1906—07.

C. Amritsar District.

(*a*) Epidemic of 1902—03.
(*b*) ,, ,, 1903—04.
(*c*) ,, ,, 1904—05.
(*d*) ,, ,, 1905—06.
(*e*) ,, ,, 1906—07.

D. Summary.

V. Later plague history of the villages infected in the course of the milder epidemics.

A. Rohtak District.

(*a*) Epidemic of 1903—04.
(*b*) ,, ,, 1905—06.

B. Mozuffarnagar District.

(*a*) Epidemic of 1902—03.
(*b*) ,, ,, 1905—06.

C. Summary.

VI. Later plague history of villages infected at the end of each epidemic.

A. Rohtak District.

(*a*) End of epidemic of 1903—04.
(*b*) ,, ,, 1904—05.
(*c*) ,, ,, 1905—06.

B. Mozuffarnagar District.

(*a*) End of epidemic of 1902—03.
(*b*) ,, ,, 1903—04.
(*c*) ,, ,, 1904—05.
(*d*) ,, ,, 1905—06.

C. Amritsar District.

D. Summary.

VII. The question whether plague tends to recur in villages in successive epidemics

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

I. Introduction.

A. *Scope of observations.*

It is well established that plague, once it has gained a foothold in a place, tends to recur every year at the same season and that the plague season varies in different places. It has been demonstrated that in Bombay City the periods between the epidemics are bridged over by cases of acute plague amongst the rats accompanied by a few cases in man. Knowing, then, the factors which determine the rise and fall of the epizootic amongst the rats, once the infection is present, we have a fairly complete conception of the seasonal prevalence of human plague in a city such as Bombay. In the case, however, of a large province, such as the Punjab, with scattered villages, the question of the annual recrudescence in the several villages is not so simply answered. For, it will be remembered that in the two Punjab villages of Dhand and Kasel, which were under close observation by the Commission for a whole year, no acute plague was found amongst either man or rats in the long interval between the epidemics. While this is so, a certain number of rats were caught alive, which, although apparently in good health, harboured living and virulent plague bacilli in chronic abscesses (see above, p. 335).

It is, however, to be noted, that after a careful study of this condition the Commission came to the conclusion that there was no direct evidence that "resolving" plague, as it occurs in the Punjab villages, possessed any significance in the seasonal recurrence amongst the rats of the infection in an acute form, nor was any evidence available which excluded this possibility. Since the observations were made in the Punjab this condition has been further carefully studied in Bombay, Poona and Belgaum, and, as we shall see elsewhere, the conclusion has been come to that the lesions denote rather a gradual and slow recovery from an acute condition than a definite chronic state. From these facts it is evident that we are still without certain knowledge of the cause of the beginning of plague in successive epidemics in the villages of India. It is this problem to which we now give attention.

On consideration of the problem two solutions seem possible. We shall for brevity designate these two hypotheses (1) recrudescence and (2) importation. Recrudescence implies that in each village each successive epidemic has its origin *in situ* from remnants left over from the previous epidemic no matter how far distant, or in other

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

words, that dregs of the infection remain over from one epidemic and light up to start the next epidemic. It implies, therefore, that plague bacilli in each village survive the interval between two epidemics. From the work which we have already done it is certain that to fulfil this condition the bacillus must find a habitat in an animal body.

Importation, on the other hand, implies that the great majority of the villages became infected each epidemic by the bacilli being brought into them from without. As the bacillus must survive the non-epidemic season in some way or other, we have to postulate for this hypothesis that the infection in one or more villages or towns bridges over the off-season as scattered cases of acute rat plague and perhaps human plague or in some other way. From the centres or foci where this bridging over takes place the infection would spread out, when the conditions become suitable, exactly as must happen when a district becomes infected for the first time. The villages in which the infection is carried over the off-season might of course vary in different years.

The problem then which lies before us is to *determine the relative importance of recrudescence and importation in the spread of the epidemic through a district with scattered villages.*

We have now to state the methods which were adopted to find a solution for this problem. Three districts in the Punjab and in the United Provinces were selected, for the reasons that they had suffered from several consecutive epidemics of plague and that in the offices of the civil surgeons records of the deaths reported from the villages of the districts were available for analysis. A complete list of the villages in the district was prepared by the clerks in the civil surgeons office, men who knew the districts and who had kept the records. Against each village was shown its population and whether it had at any time been plague-infected or not. If it had at any time reported plague deaths, the following information for each epidemic was entered: the date of the first death, the date of the last death, and the total number of deaths. If the interval between the first and last death was more than three or four months, namely, the normal duration of a single epidemic in a village, the number of deaths month by month was recorded, so that any period of freedom from deaths might not escape notice. These data obtained from the district records have been analysed chiefly in the following directions.

First, maps have been prepared showing the infected villages month by month for several years from the first introduction of plague into

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

the district. In these maps we are able to trace the spread of each epidemic and to compare the later epidemics with the first one, which we know must have spread by importation. The rise of each epidemic can also be graphically followed and can be correlated with the decline of the previous epidemic. The maps of Rohtak district are reproduced.

Secondly, the previous plague history of the villages infected in each epidemic has been determined with the object of obtaining data regarding the relative proportion of those which had never been infected before, of those which had been infected during the previous epidemic and of those which had escaped for either one or more epidemics.

Thirdly, in those villages in which the disease appeared first in each epidemic the previous history as regards plague infection, especially in the epidemic just passed, has been traced.

Fourthly, in some districts only a small number of villages were infected in one or more of the epidemic years. We have traced the fate of all these villages in the following year in which the epidemic was widespread and involved a very large number of the villages of the district.

Fifthly, we have followed in detail the future history as regards plague infection of villages infected at the end of each epidemic, so as to ascertain in what proportion of them deaths were reported early in the next epidemic.

Finally, we have investigated the question whether plague tends to recur in villages in successive epidemics, and have also analysed the relation of the size of a village to its liability to become infected.

In considering the results obtained in this way, it is necessary to bear in mind the limited accuracy of the records. In particular they tell us nothing of rat plague which is not accompanied by obvious human plague. The fact for example that a village has not returned a plague death is not an absolute proof that there has not been a small rat epidemic, accompanied perhaps by a few mild human cases. It is therefore possible that the first year of infection of any village is recorded as being later than it really was. It is, however, impossible to estimate the weight of these possibilities. Considering the intimate domestic relationship of rats and human beings in the Punjab villages, it seems to us unlikely that rat plague could often exist without being indicated by human plague; where this is known to have occurred, the conditions have been very different. In any case, we have no choice but to deal with the data as they stand: we have little doubt that they give a substantially accurate picture of the incidence of plague infection in the villages concerned.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

B. *Districts in which observations were made.*

(1) *Rohtak.* Rohtak is a small district in the south of the Punjab. It is about 64 miles long by 43 miles broad and has an area of about 2800 square miles. There are no natural boundaries such as rivers, etc., so that there is free intercourse on all sides. The total population is about 620,822 which gives a density of 0·3 per acre.

There are 499 municipal towns and villages, none of which, however, are very large. There are only three municipal towns, namely, Rohtak (pop. 20,024) and Beri (pop. 9723) in the Rohtak subdivision, and Jhaggar (pop. 12,227) in the subdivision of the same name. The position of these towns is shown on the maps. All other settlements are villages with a population of less than 8000. The average population per village is 1244.

The district is divided for administrative purposes into four subdivisions or tehsils; Gohana in the north, Jhaggar in the south, and two in the centre, namely Rohtak to the west and Sampla to the east. A few details concerning the distribution of the population in the different tehsils are given in Table I. The point in this table to which we would especially draw attention is the relatively small average population of the villages in the Jhaggar tehsil. While the total population of this tehsil is the smallest of all, it is divided up amongst the greatest number of villages, so that the average population per village is from $\frac{1}{2}$ to $\frac{1}{3}$ that of the other tehsils.

Plague was introduced into the Rohtak district in the winter of 1903—04, the first deaths being reported in the Rohtak tehsil in November 1903. Up to July 1907 there were four epidemics, two slight ones alternating with two severe ones (vide Table II). Of the 499 villages in the district 145 were not infected in any of the epidemics, leaving 354 which returned deaths in one or more of the epidemics.

The seasonal prevalence of the epidemics was well marked (Table III). The deaths began to increase each year in the autumn (September —October) or early winter (November—January). The increase continued until a maximum was reached in April or May, after which there was a sudden fall in June. During July and August only a few villages returned deaths or sometimes none at all.

(2) *Mozuffarnagar* is a district in the north of the United Provinces, not far from the southern boundary of the Punjab. It is bounded on the west by the river Jumna, while all along the east side runs

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

the sacred Ganges. On the north and south there are no natural boundaries. The total population of the district is about 917,896. There are 973 inhabited municipal towns and villages, so that the average population per village is 944. There are only three towns with a population of more than 10,000, namely Mozuffarnagar (23,444), Kairana (19,304), and Kandla (11,563). All the other villages have less than 9000 inhabitants each.

The division of the district into thanas has been adopted for our present purpose. There are 18 of these subdivisions in the district.

Plague was first introduced into the Mozuffarnagar district in January 1902. Up to the summer of that year only four deaths were returned, so that it is improbable that there was any indigenous infection in that season.

In November 1902 the epidemic began in earnest and from then up to 1907 there have been five epidemics, the data referring to which are given on Table IV.

Of the 973 villages in the district, 334 have been at no time infected leaving 639 which have reported deaths in one or more of the epidemics. The seasonal prevalence of the epidemics has been well marked. The deaths began to increase each year in the autumn (September—October) or early winter (November—January). The maximum was reached in April, after which there was a fall until by the end of June the epidemics had practically ceased (Table V).

(3) *Amritsar.* Amritsar is a moderate sized district in the centre of the Punjab lying a short distance from the foot of the Himalayas. It has an area of 1601 square miles, the total population being 1,039,620 which gives a density of about 1 per acre.

Along the south-east limits of the district runs the Beas river, while on the north-west the Ravi separates it from the Sialkot district. There are no natural boundaries along the other two sides of the district, which is roughly square in shape. The main line of railway runs practically from east to west and the district is further intersected by many canals, the general direction of which is from north-east to south-west. There are four municipal towns and 1058 inhabited villages. Of the former Amritsar, the chief town of the district, is by far the largest, its population being 162,429. The three other municipal towns Tarn-Tarn, Majitha and Jandiala have a population between 4428 and 7877. Only very few of the villages have more than 4000 inhabitants. The average population per village, including the municipal towns, is 978. The district is divided into three tehsils,

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

namely Ajnala in the north, Amritsar in the centre, and Tarn-Tarn in the south.

Plague deaths were first reported from the Amritsar district in February 1902. This epidemic, beginning late in the plague season, had only affected 62 villages when the hot weather limited its further spread. Succeeding this mild outbreak there have been five more or less severe epidemics (Table VI), the mildest being that of 1905—06 in the course of which about a quarter of the villages in the district became infected. The other four epidemics have all been severe, in each instance about half or more of the villages returning plague deaths. There were, therefore, three consecutive seasons, 1902—03, 1903—04, and 1904—05, during which the district was badly infected, a condition of affairs somewhat different to that which has been described as occurring in the Rohtak district, in which two mild epidemics alternated with two severe ones.

Of the 1062 towns and villages in the district 907 have in the course of one or more of the six epidemics returned plague deaths, leaving 155 which have not at any time been infected.

As was observed in the other two districts the seasonal prevalence had been well marked (Table VII). Each epidemic, beginning in the autumn or early winter, has gradually gained strength until the height was reached in April or May. After May the decline has been rapid, so that by the end of July very few villages remained infected; that is to say, returned plague deaths. Finally, it is important to note that since the disease was first introduced into the district in February 1902 until the end of July 1907, there have only been two months, namely, September and October 1903, during which one or more villages did not report plague deaths. In fact, this large area has at no time even in the off-season been free from human plague and as a corollary acute rat plague must always have been present in the district.

Analysis of the data obtained.

II. Method of spread of the epidemics in each district as judged from the maps.

The maps, as we have stated, were prepared from the records of plague deaths which were available in the district plague offices. It is to be noted that the criterion of infection is the occurrence of a death

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

or deaths from plague so that when a village is spoken of as being infected it means that one or more deaths from plague have been reported among the population.

A. *Rohtak District.*

Maps I—XLVIII[1].

(*a*) *Epidemic of* 1903—04. Deaths began to be returned in November 1903 from two separate villages in the extreme west of Rohtak tehsil and from Beri town situated to the south of the district.

In January 1904 the pattern suggests a slight spread out from Beri and there appears a fresh infection in the extreme south of the Jhaggar tehsil. The maps of the following months show a well marked spreading out from the Beri centre and also an increase of infected villages round about those which first returned deaths in the west and south of the district. The town of Rohtak, the largest in the district, did not become infected till late in the epidemic, namely in April, and there was hardly any spread to the northern portion of the district, the Gohana tehsil remaining practically free. In June the epidemic subsided and in July only one village, to the west of Beri, still reported deaths.

It is important to keep in mind the pattern of these maps. The villages were all infected for the first time, so that the origin of the infection in each case was presumably due to importation. The pattern as we have seen suggests a spreading out as the epidemic progresses from two if not from three foci, into which the disease was introduced at the beginning of the epidemic.

(*b*) *Epidemic of* 1904—05. This epidemic began in August 1904, that is to say, there was no month between it and the end of the previous epidemic in which plague deaths were not reported from the district. In August two villages returned deaths, one in the Rohtak tehsil quite close to Beri and the other in the south of Jhaggar. It will be remembered that in 1903—04 both these localities had been infected. Further, one of the villages, namely, that in Rohtak, had itself been infected as late as May: the other village had not previously reported deaths.

In September there appears to be a slight spread out from the Beri centre and a new centre crops up in the Gohana tehsil. This latter

[1] In the months for which no maps are given there was no plague in the district. The circles represent epidemics with less than five plague deaths.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

village, although not itself previously infected, is situated next to the only village in this tehsil which was infected in the previous epidemic, and in which deaths took place as late as June. It is also worthy of note that the three villages in the neighbourhood of the Beri centre had all been infected late in the last epidemic, two as late as June and the third one up to May.

The October map shows a slight increase of the number of infected villages in the neighbourhood of Beri. Rohtak town is now also infected.

In November and December more infected villages appear around Beri and also in the neighbourhood of the centres established in August in the south of Jhaggar tehsil and in September in the north in Gohana.

It is evident, therefore, that by the end of December the infection had become fairly widespread. The subsequent maps show a gradual thickening of infected villages all over the district, in the January map the spread being traceable from the centres already established, especially around Rohtak town. In June the epidemic markedly subsided, the villages then infected being chiefly situated in the north-eastern portion of the district. In July only a single village returned deaths.

(*c*) *Epidemic of* 1905—06. During August and September 1905 the district was apparently free from plague as no villages returned any deaths.

In October two villages showed infection, one in the north of Gohana tehsil and the other in the south-east of Sampla. The former had returned deaths as late as June 1905 and the latter a few deaths in May 1905. Further, in June both were surrounded by infected villages.

In November and December there is little change, only one infected village in the north of Gohana being added in December. This village was also infected the previous epidemic as late as June. From now onwards the main feature of the maps is the gradual increase of infected villages in the north of Gohana, round about the villages which first returned deaths. A very few scattered villages, chiefly in Rohtak tehsil, become infected, but there is no appearance of a spread out from any centre except from the one in the north of Gohana. Here the infection lingered up to June, in which month four villages in this tehsil were still returning deaths.

In July no deaths were reported from anywhere in the district.

It is to be remembered that the epidemic of 1905—06 was a slight one, only 30 villages being reported infected.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

(*d*) *Epidemic of* 1906—07. In August 1906 a single village began to return plague deaths. It was situated in the north of the Rohtak tehsil, but only a few miles to the south of the four villages which had reported deaths in June 1906. Further this village had itself been infected the previous epidemic, the last death being reported on the 27th May.

In September three more villages were returned infected: two in Gohana tehsil to the north of the village infected in August, and the third in the extreme east of the Sampla tehsil. Of these three villages only one of them had been infected in 1905—06, the last death taking place on 10th June, 1906.

In October again three new villages reported cases, two in Gohana and one in Sampla tehsil. Only one of these villages had been infected in the previous epidemic.

During the next two months a few more villages in the northern portion of the district became infected making 11 villages which up to the end of 1906 returned deaths. It is important to note that of these 11 villages only four had been infected in the previous epidemic, the others having been apparently free from plague in every instance for at least 15 months. Further, up to the end of December, the infection was entirely confined to the north and east, especially the north, portions of the district.

The remaining maps of this epidemic show a gradual thickening of the infected villages in the north-east with a later incursion into the centre and over the centre into the west. Rohtak tehsil in the west is infected late, namely March, April and May, while Jhaggar in the south is hardly infected at all. In this tehsil up to the end of March only four villages had reported deaths, not one of which had been infected in the previous epidemic. The pattern in short suggests a spread out from the centres established early in the north and east.

B. *Mozuffarnagar District.*

The first plague death in the district was reported from Mozuffarnagar town in January 1902. This was probably an imported case as nothing further happened.

In April of the same year a village, Biralsi, in Charthawal thana reported three deaths. As there was no further sign of infection in this place till December 1904, these also were probably not indigenous cases.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

No more deaths were returned until November 1902, when the first epidemic began.

(*a*) *Epidemic of* 1902—03. This epidemic was a small one, only 25 villages becoming infected. It was entirely confined to the south-east half of the district suggesting that the invasion had taken place from this direction. It is interesting to note in passing that the railway passes from south to north through this portion of the district.

With the exception of the thana of Budhana, in which several villages close together returned deaths, the patterns of the maps do not suggest a spread out from any definite centres, the villages which became infected being all widely separated from one another. We would especially draw attention to this springing up of the infection in villages at a distance from one another. This fact is of the greatest importance as, it is to be remembered, we are now dealing with the first epidemic in the district when every village presumably owed its infection to importation.

(*b*) *Epidemic of* 1903—04. The epidemic of 1902—03 came to an end in the month of June 1903. During July and August of this year no villages reported plague deaths.

The epidemic of 1903—04 began in two towns, both of which had been infected late in the previous outbreak and showed an interval of only three months free from deaths.

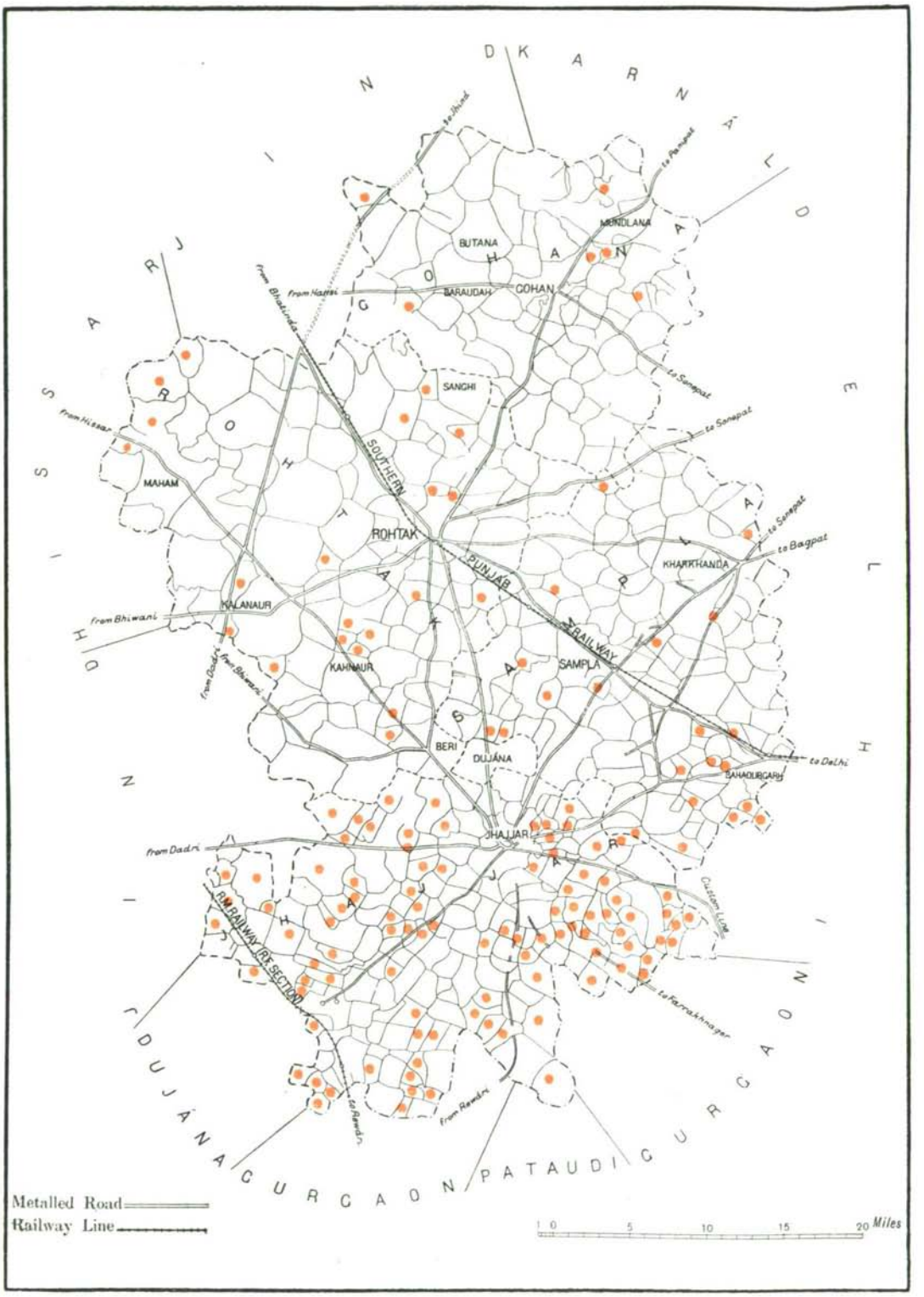
The patterns of the maps suggest a spread out from these centres and at the same time the development of fresh infections further afield, which villages again become the centres of spread. It is to be noted that the great majority of the villages which reported deaths in this epidemic had never been infected before. Thus of 130 villages which returned cases, only nine of them had been infected in 1902—03, so that in the case of at least 121 (93 %) villages the origin of the outbreak may be attributed to importation.

(*c*) *Epidemic of* 1904—05. Taking this epidemic to have begun in July 1904, there was no interval of freedom between it and the previous outbreak.

Tijalhera, a village in Purkazi thana, became infected in April 1904 and reported deaths right through the off-season till 10th September, 1904; Bebra in Bhopa thana became infected in May 1904 and continued without interruption to return deaths until 7th October, 1904. In July, as well as these two villages, two others close together in Charthawal thana each reported two deaths. They had never been infected before.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP I

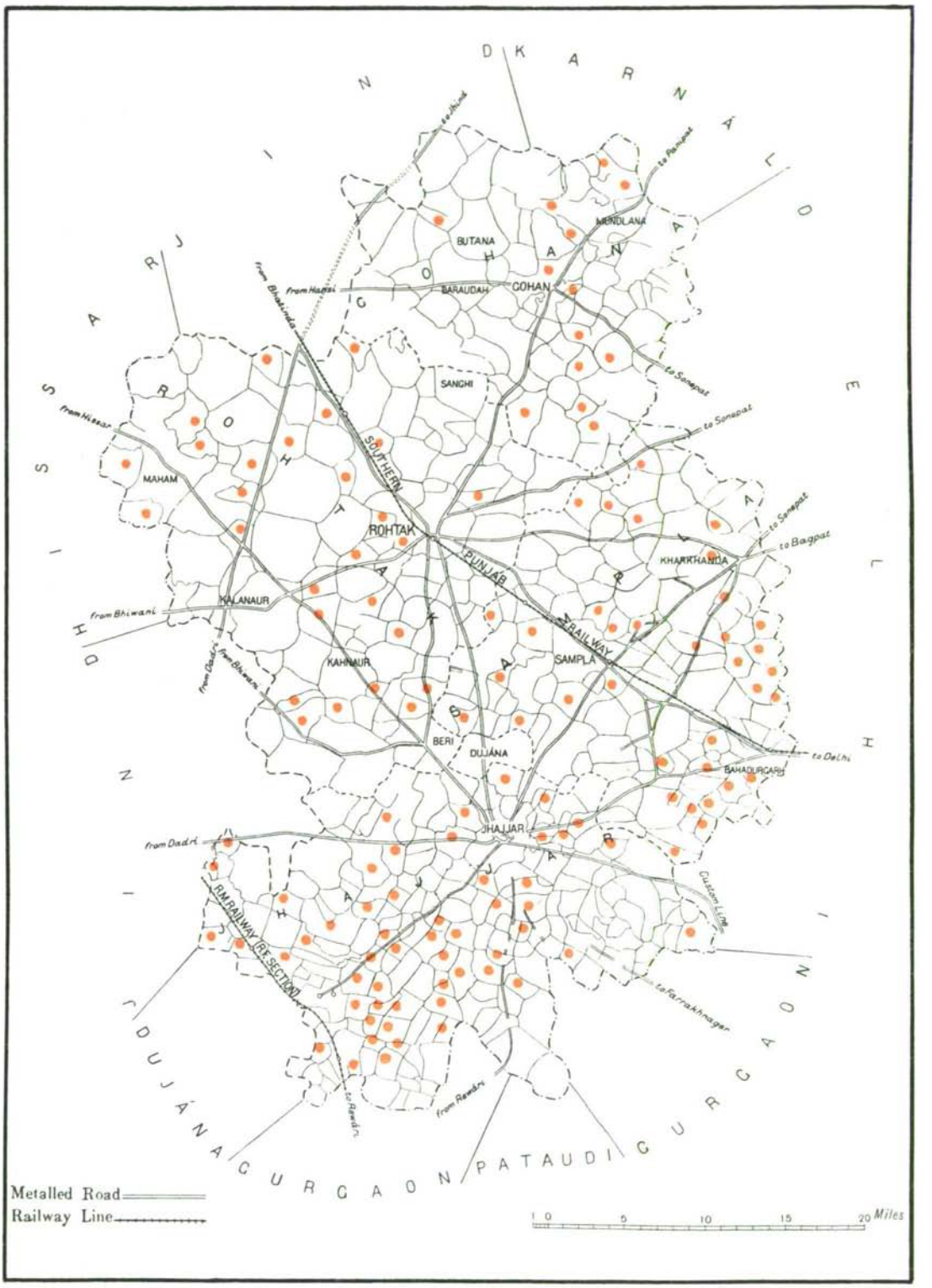


ROHTAK

Villages not infected in any of the epidemics

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP II

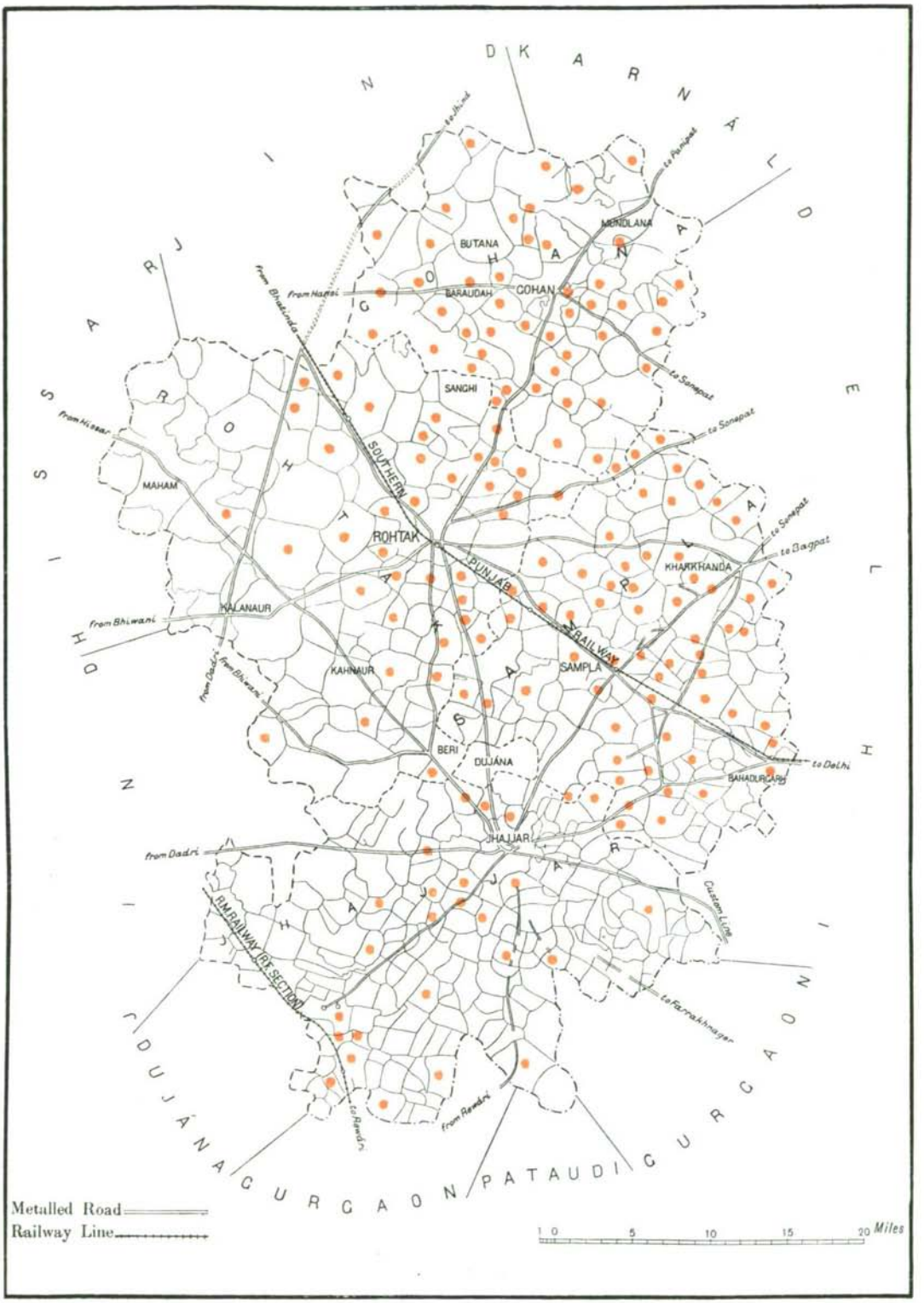


ROHTAK

Villages infected in one epidemic

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP III

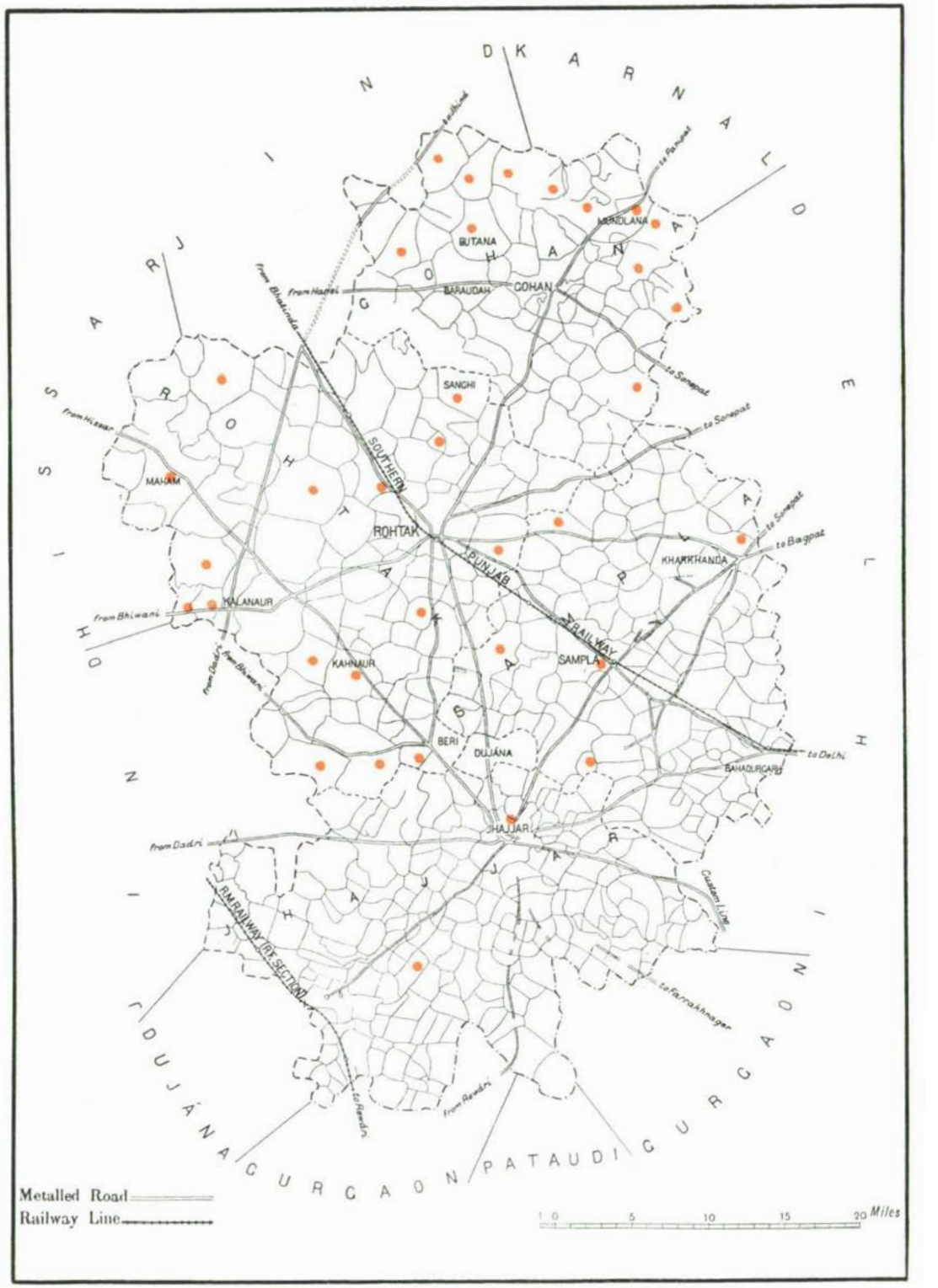


ROHTAK

Villages infected in any two epidemics

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP IV

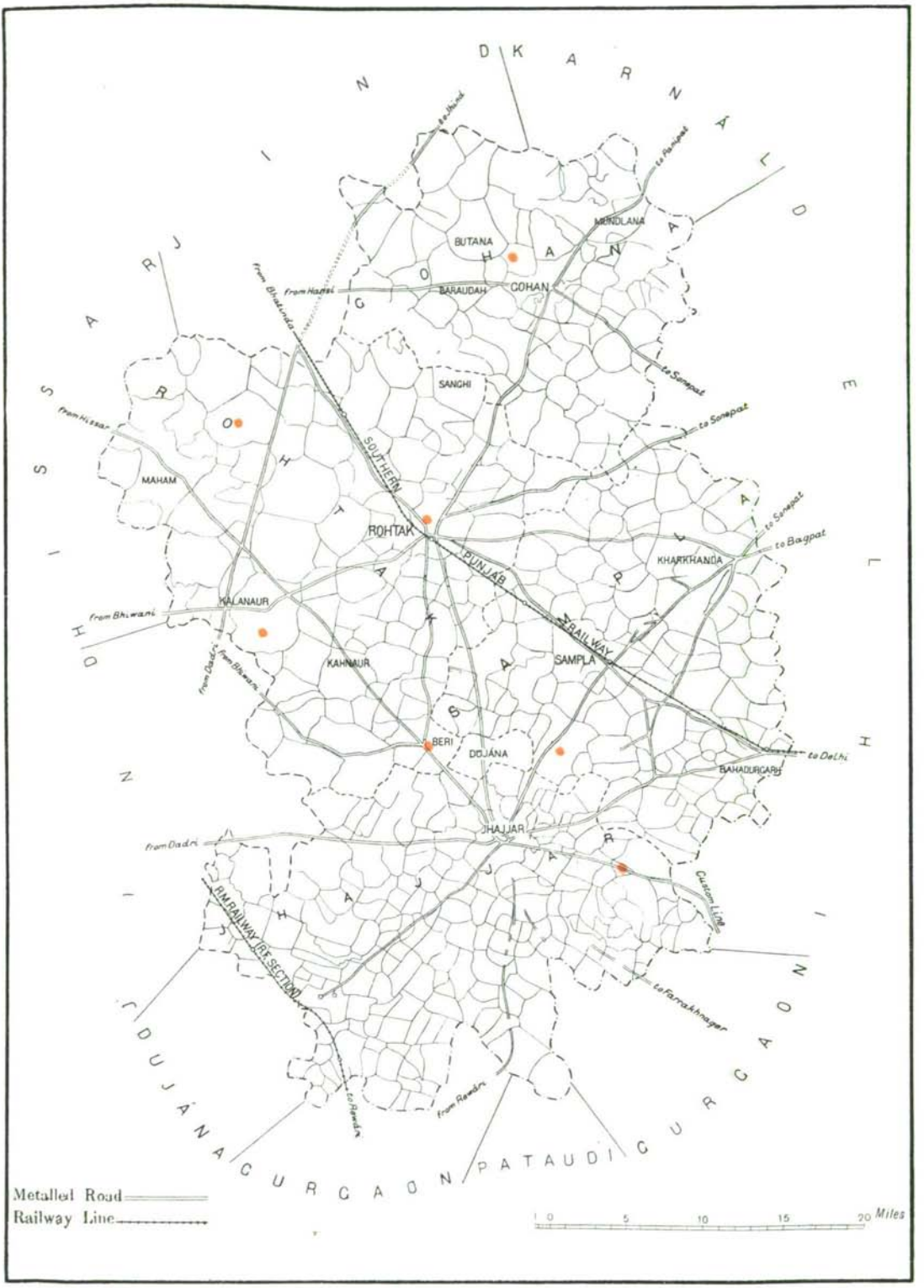


ROHTAK

Villages infected in any three epidemics

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP V

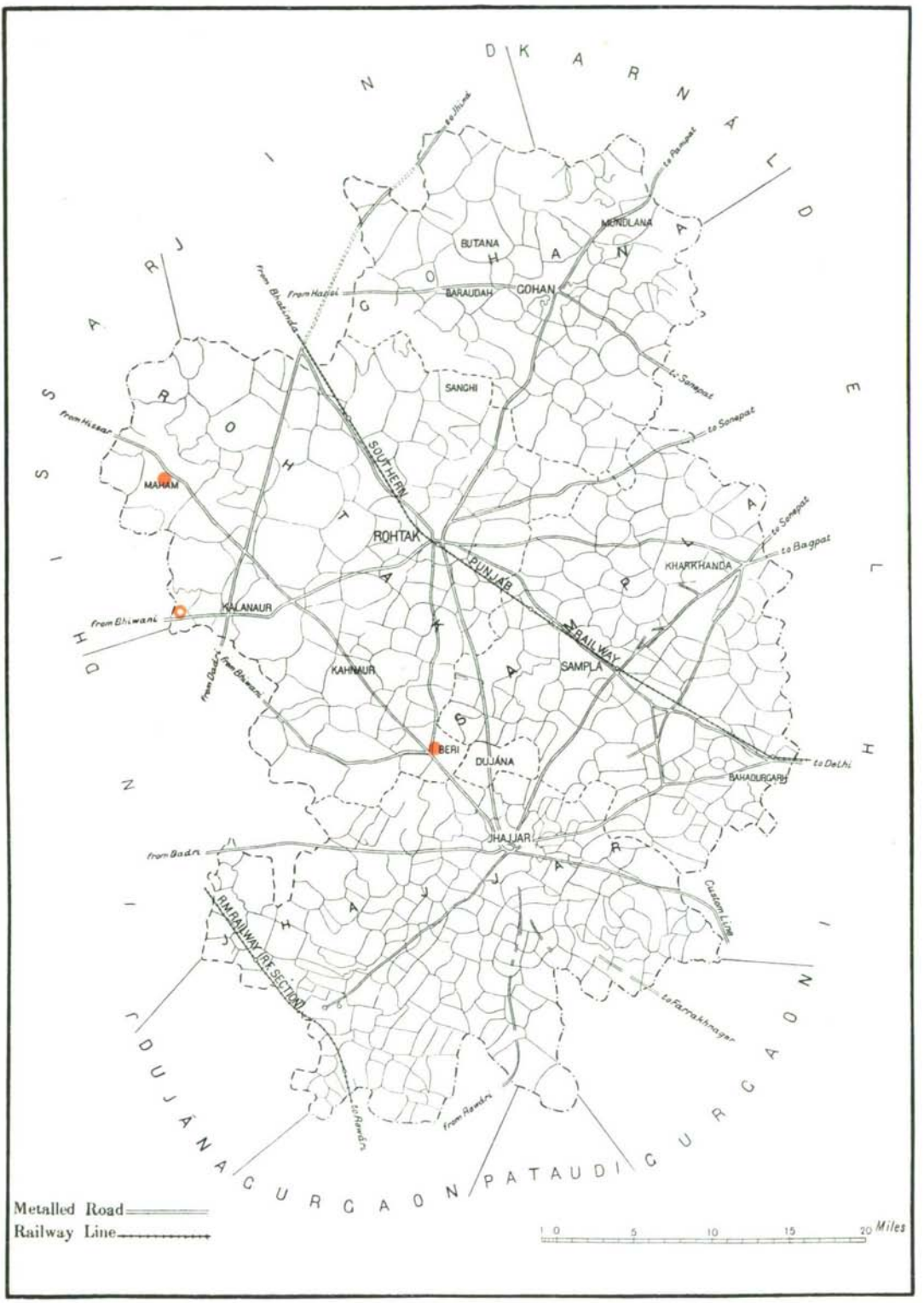


ROHTAK

Villages infected in all four epidemics

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP VI

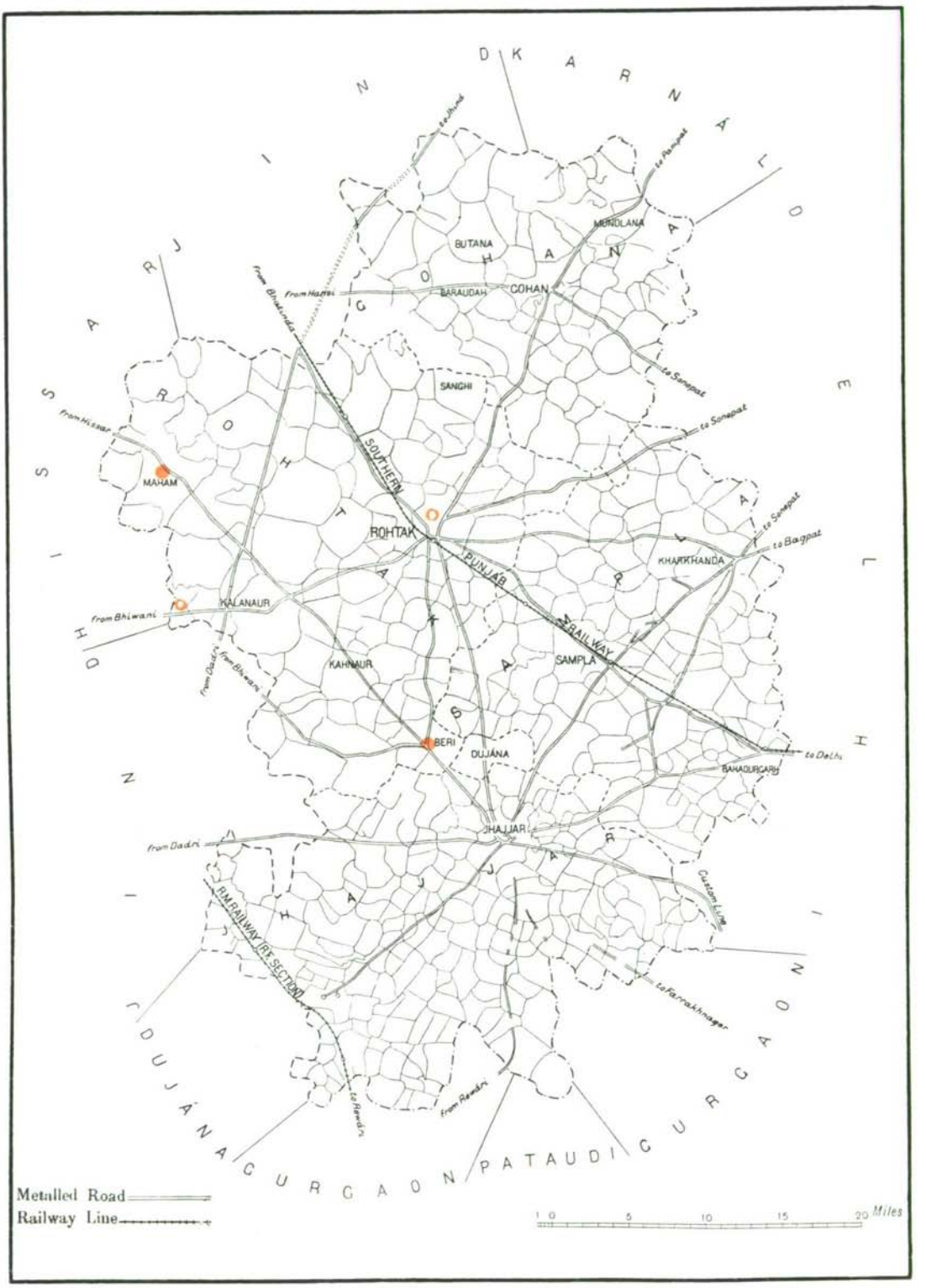


ROHTAK

November, 1903

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP VII

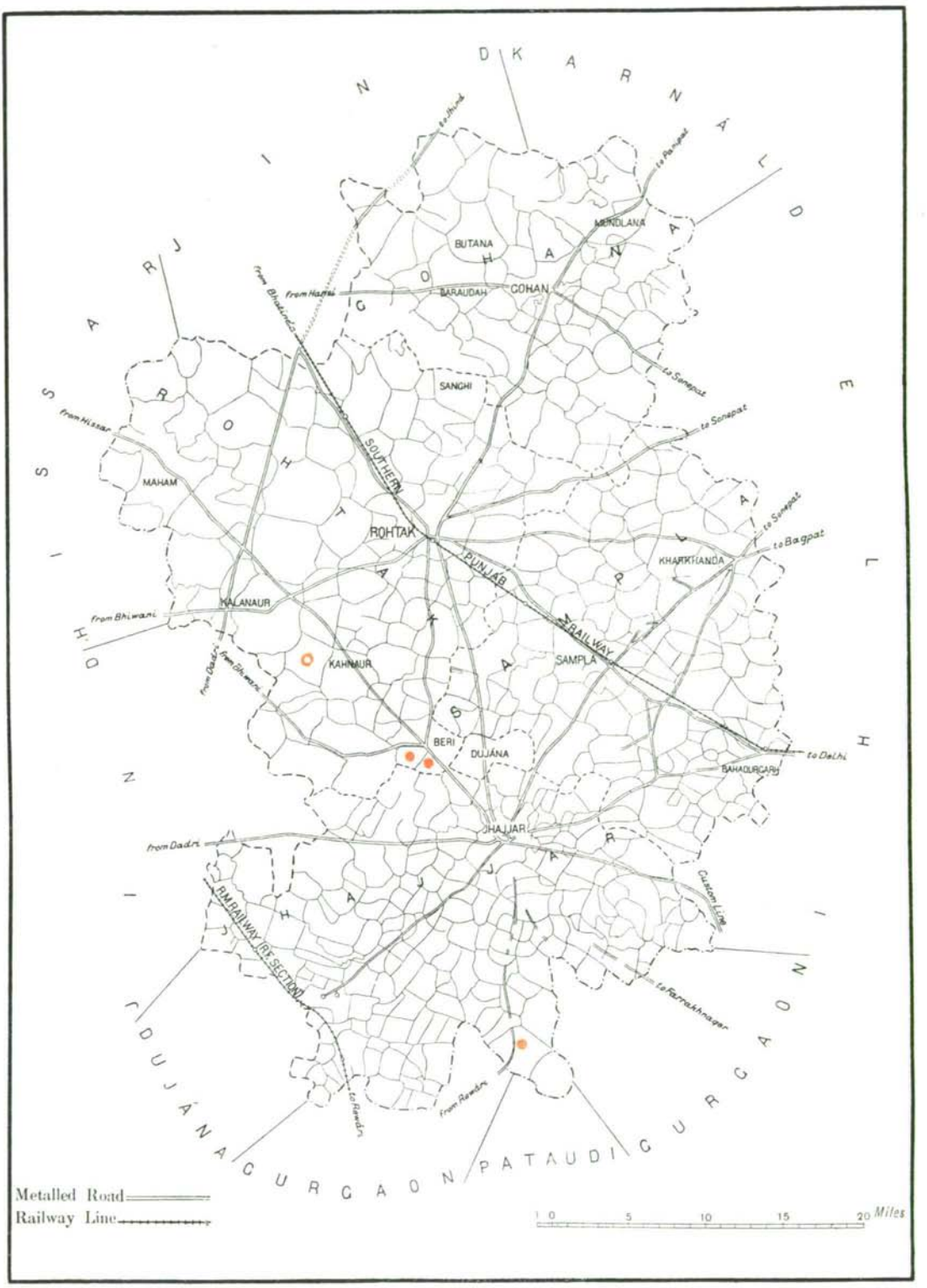


ROHTAK

December, 1903

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

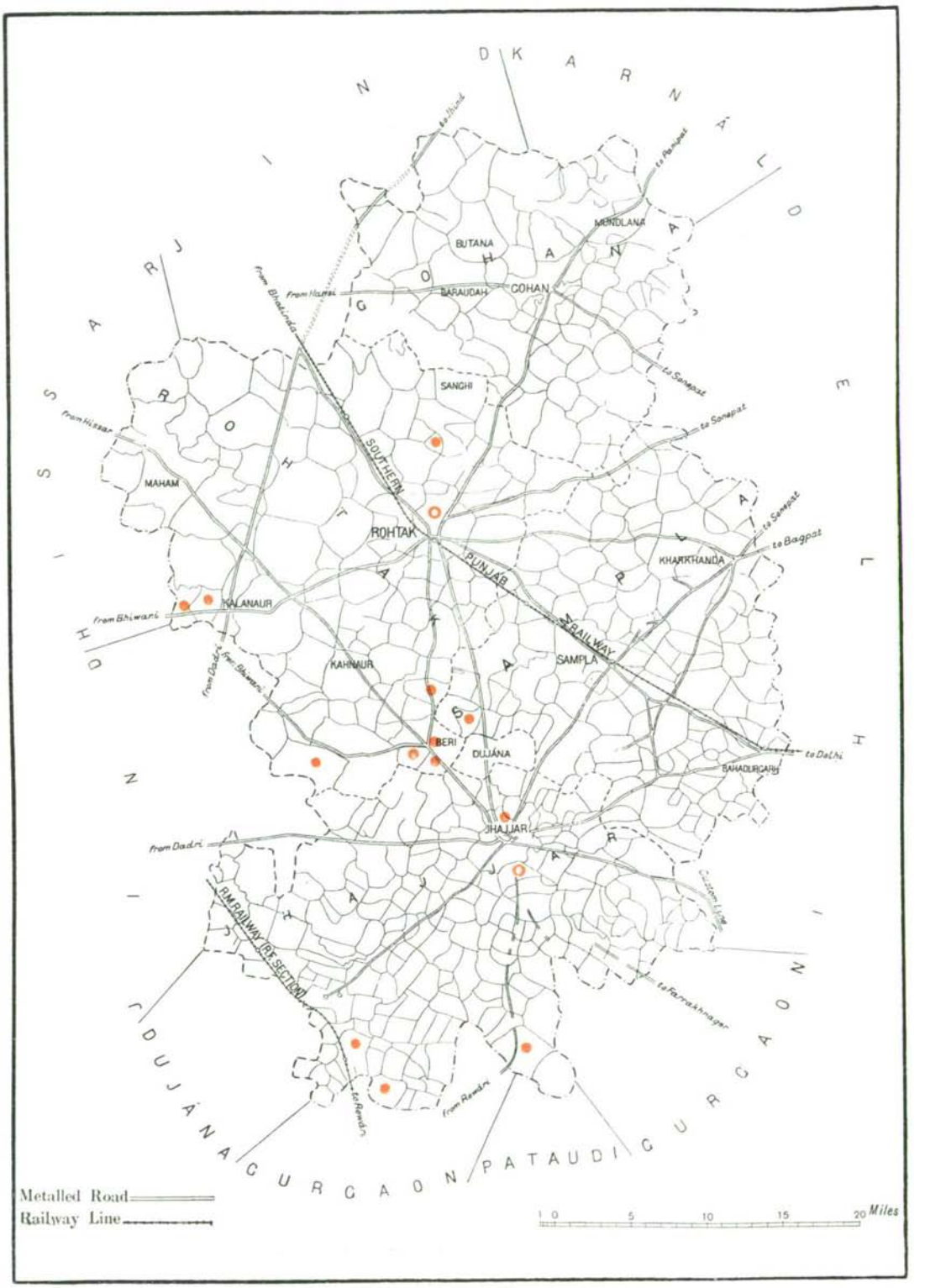
MAP VIII



ROHTAK

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP IX

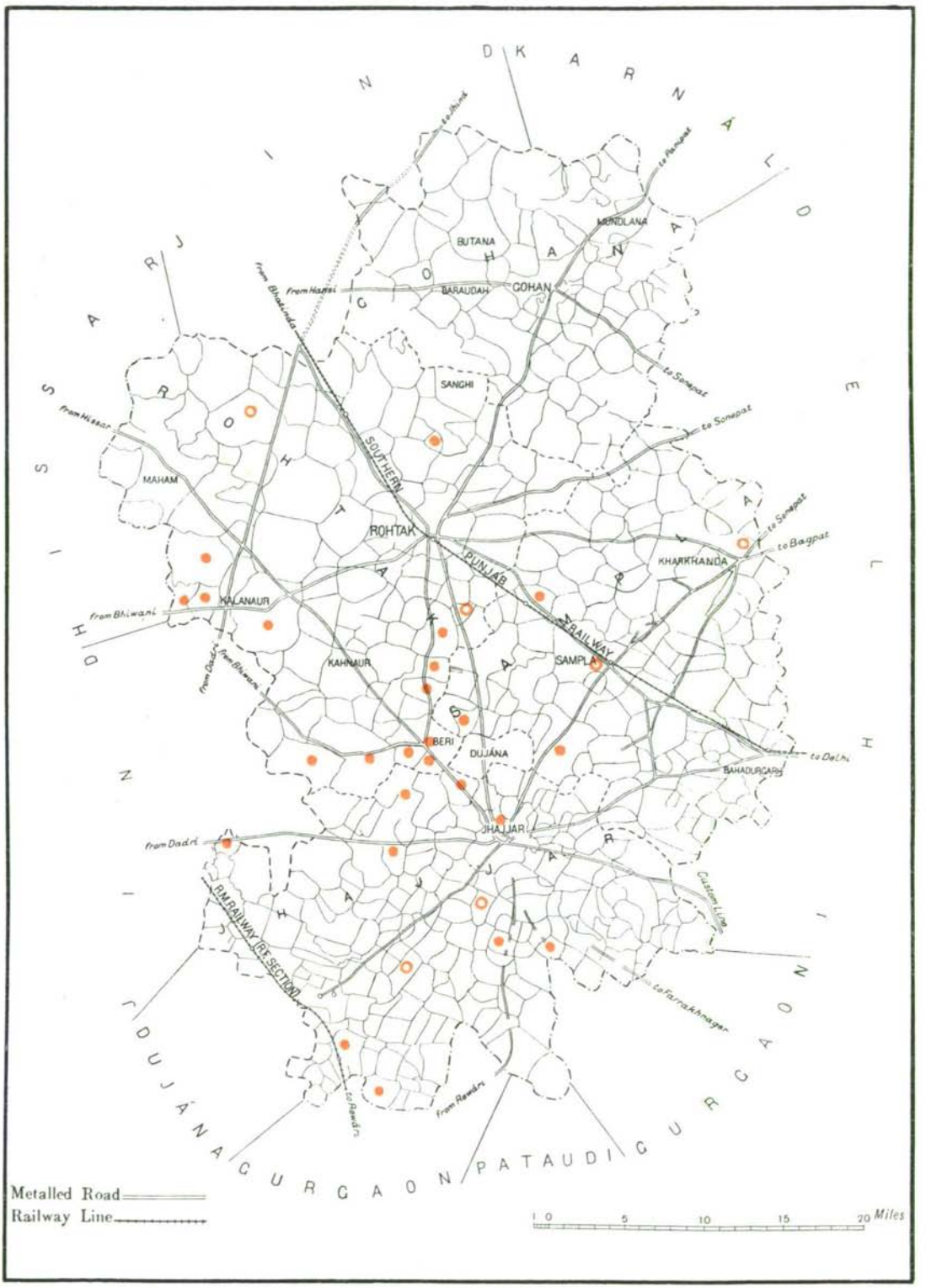


ROHTAK

February, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP X

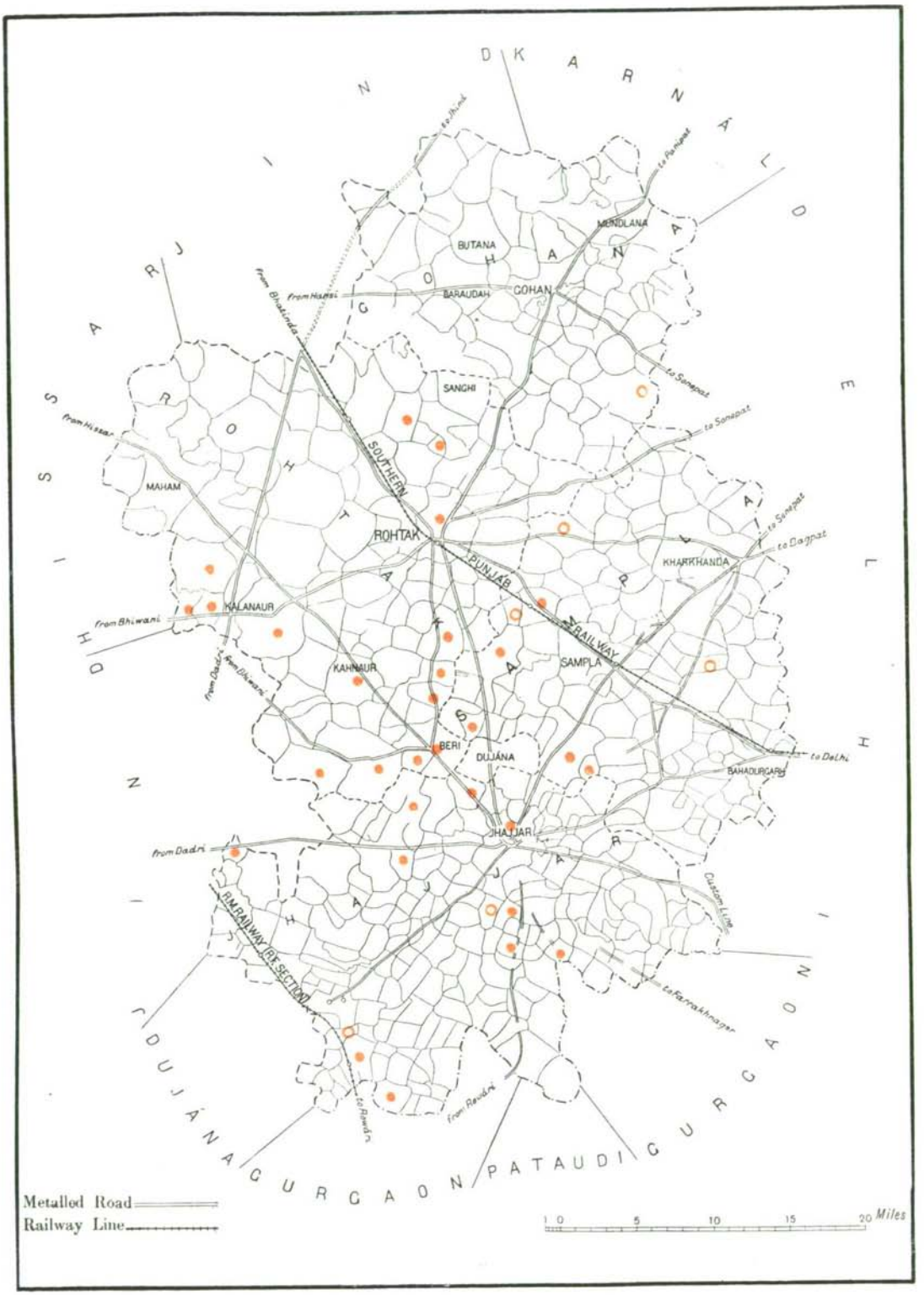


ROHTAK

March, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XI

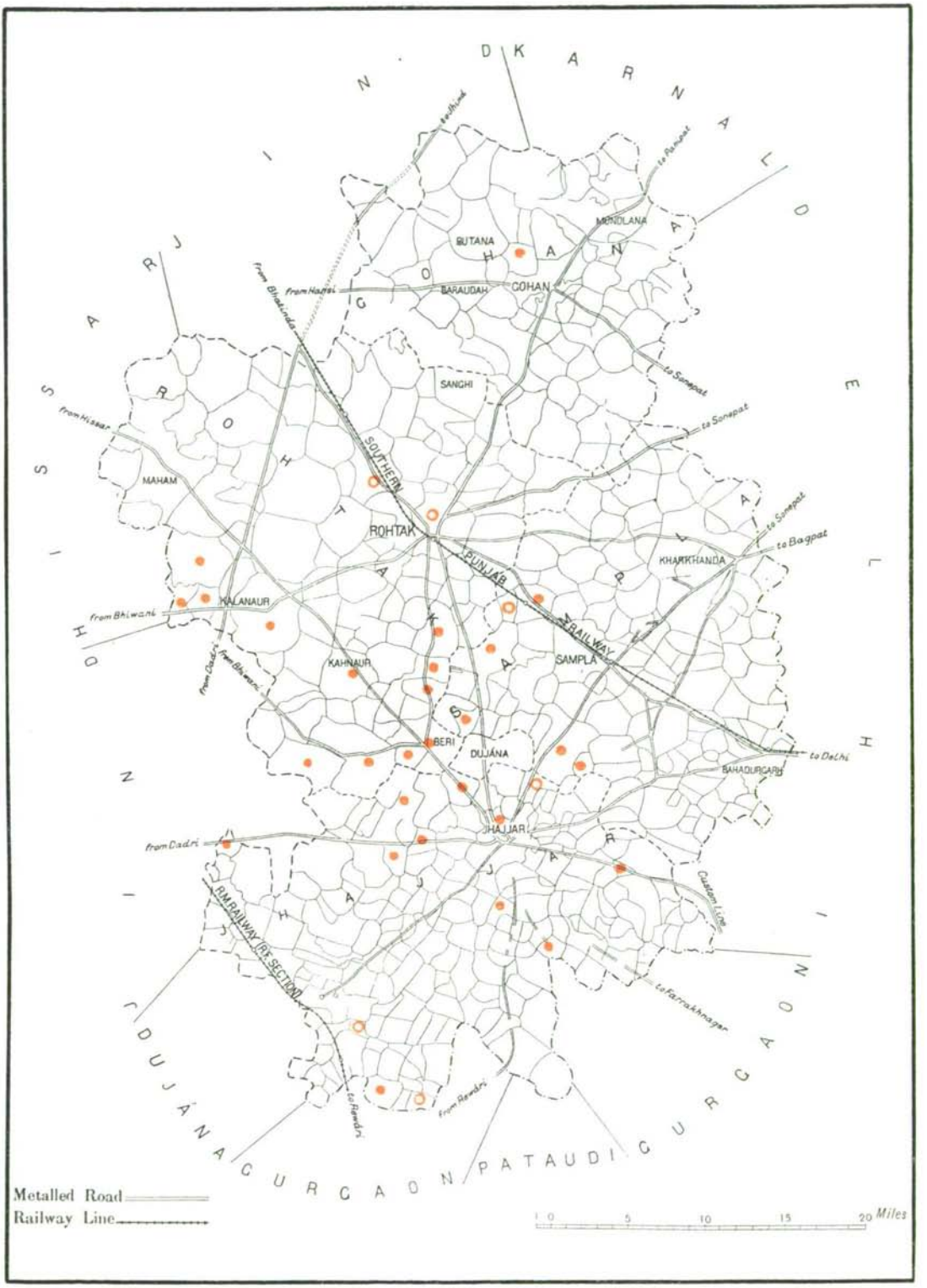


ROHTAK

April, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XII

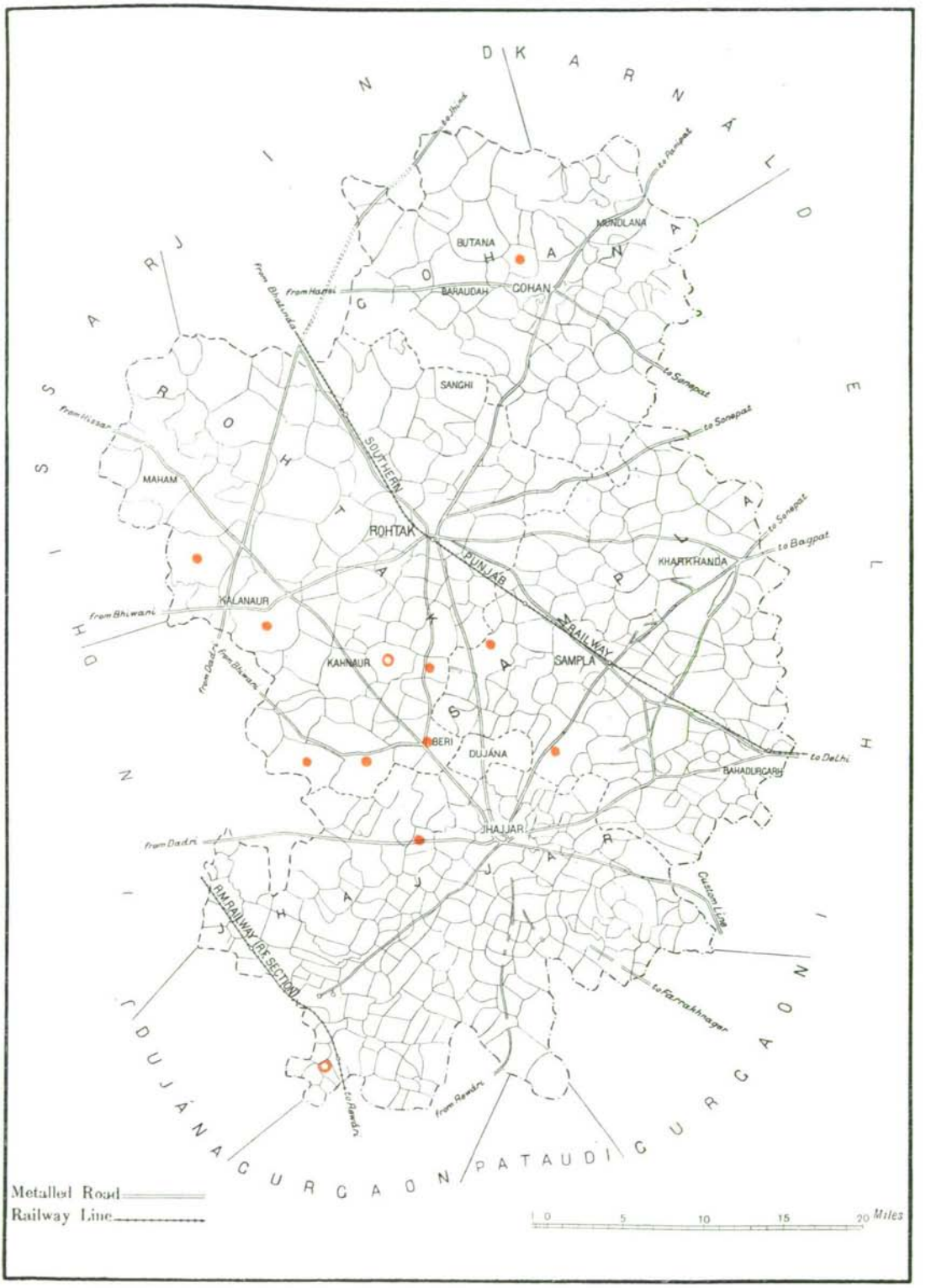


ROHTAK

May, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XIII

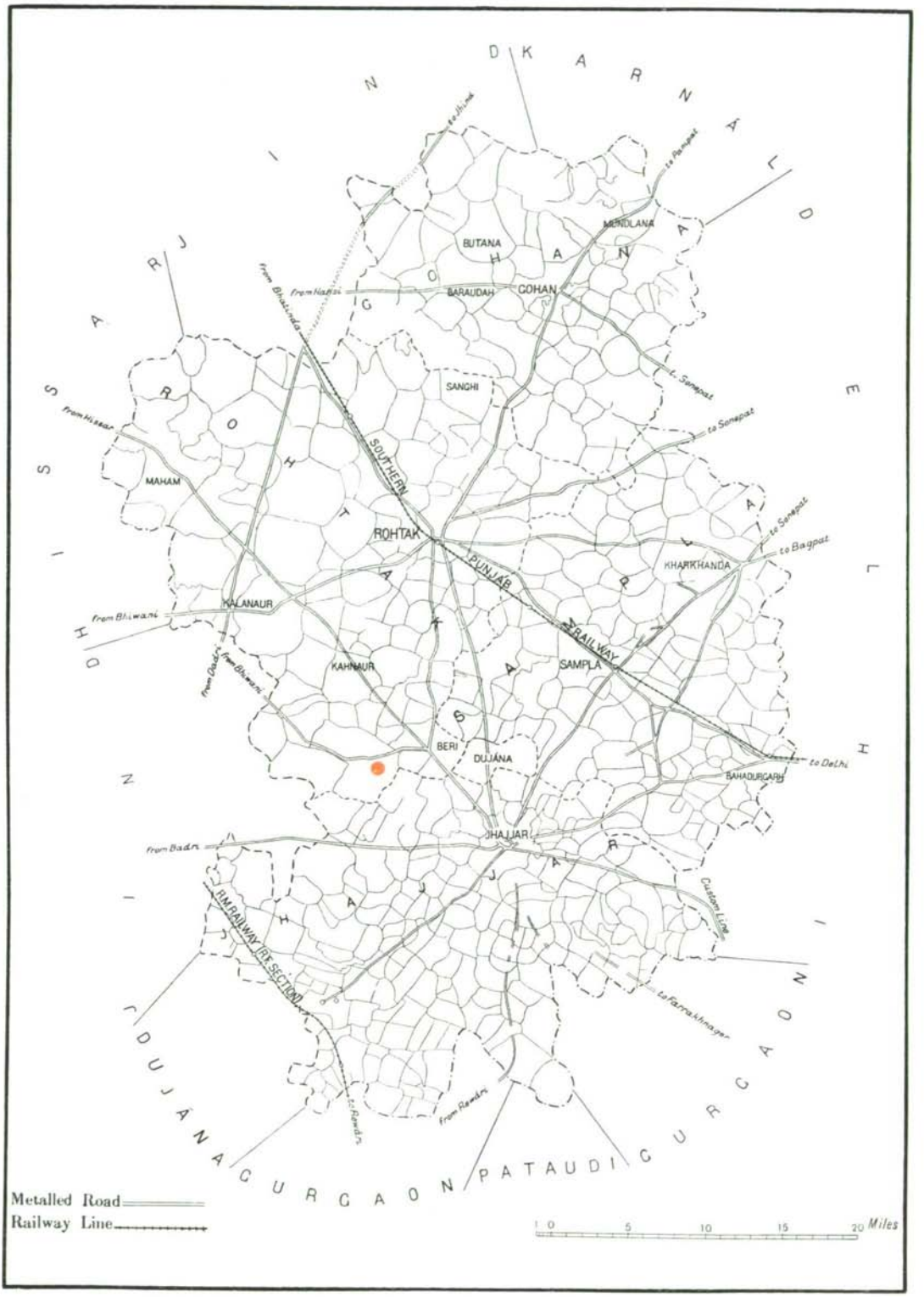


ROHTAK

June, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XIV

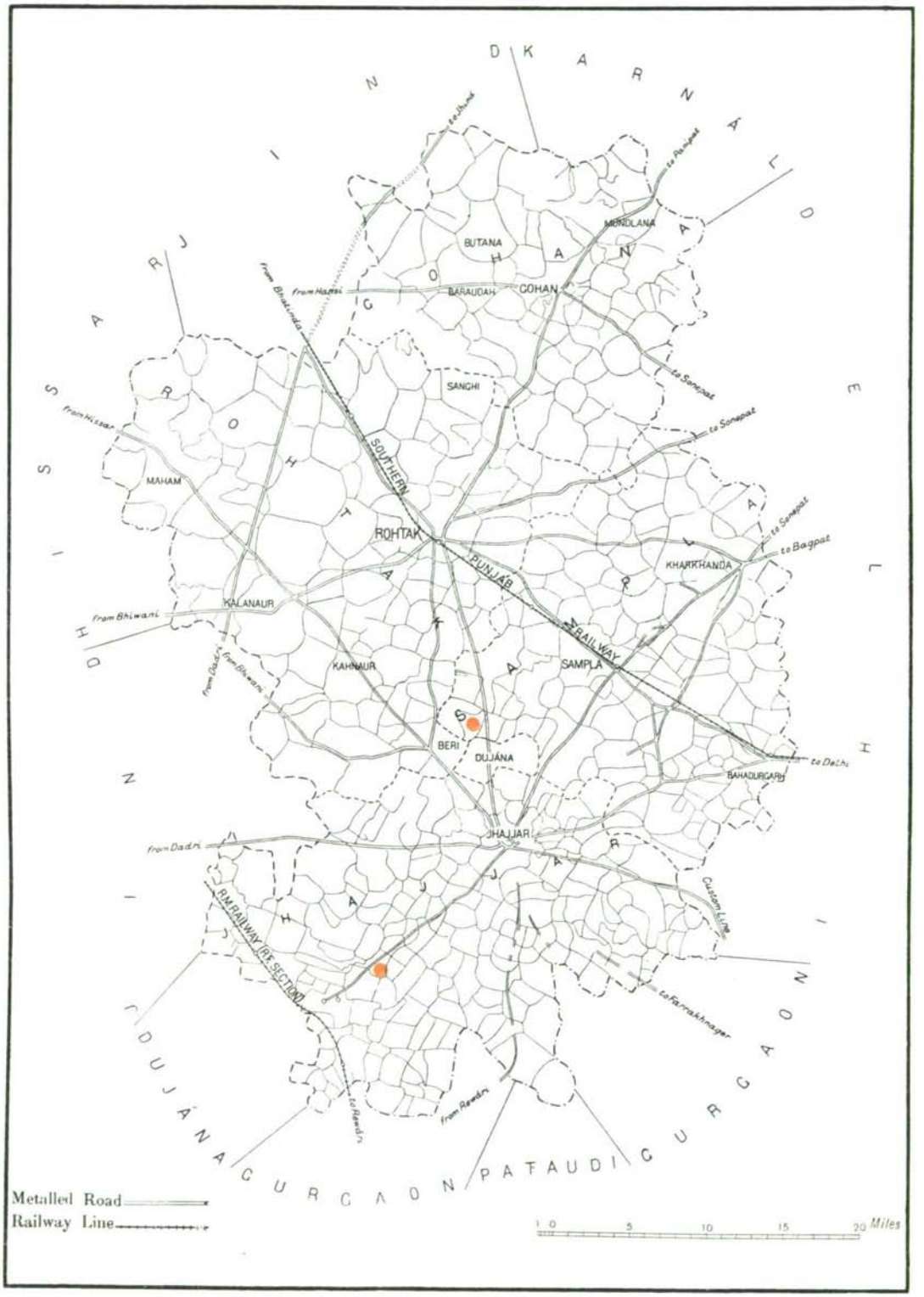


ROHTAK

July, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XV

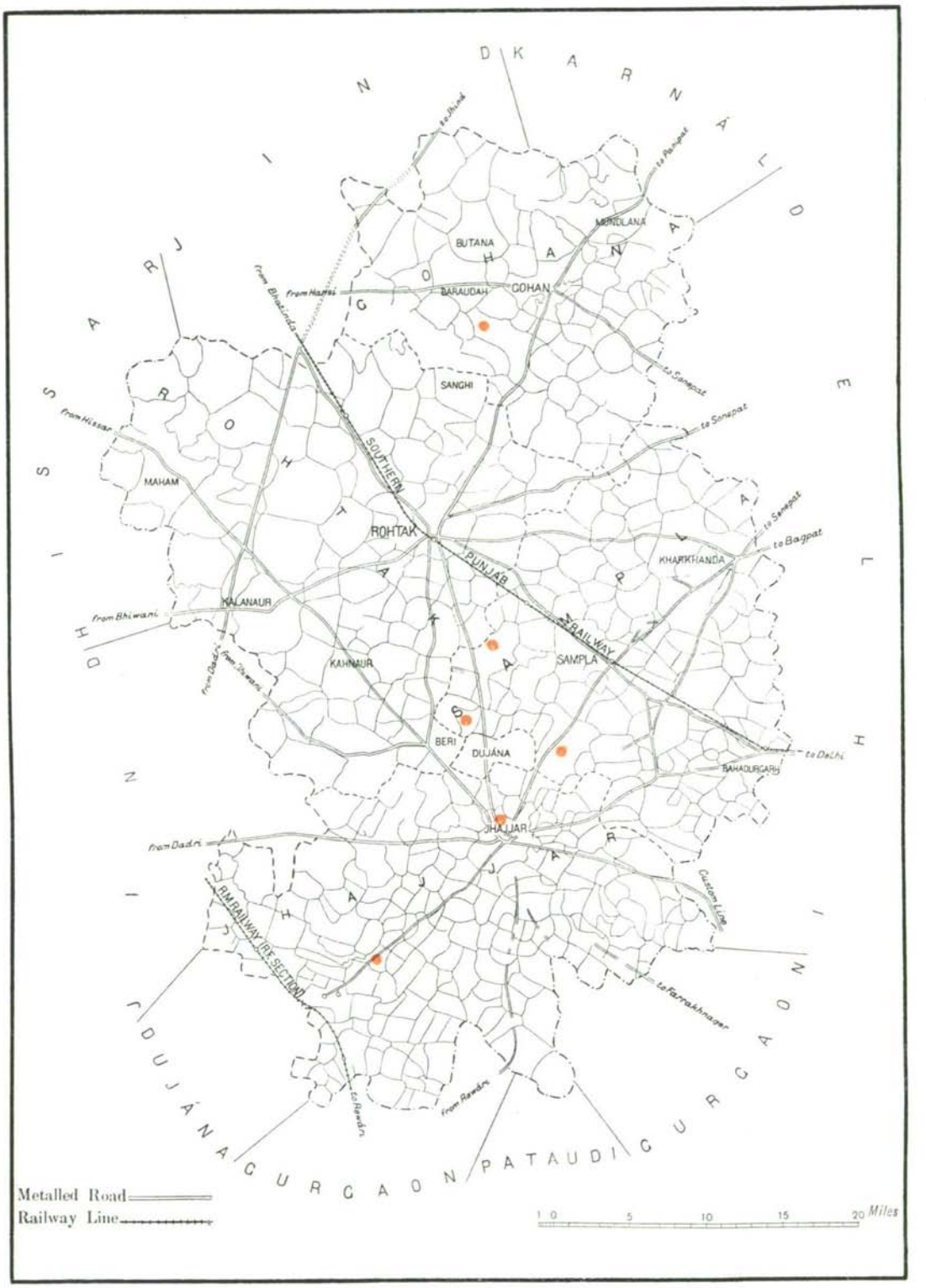


ROHTAK

August, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XVI

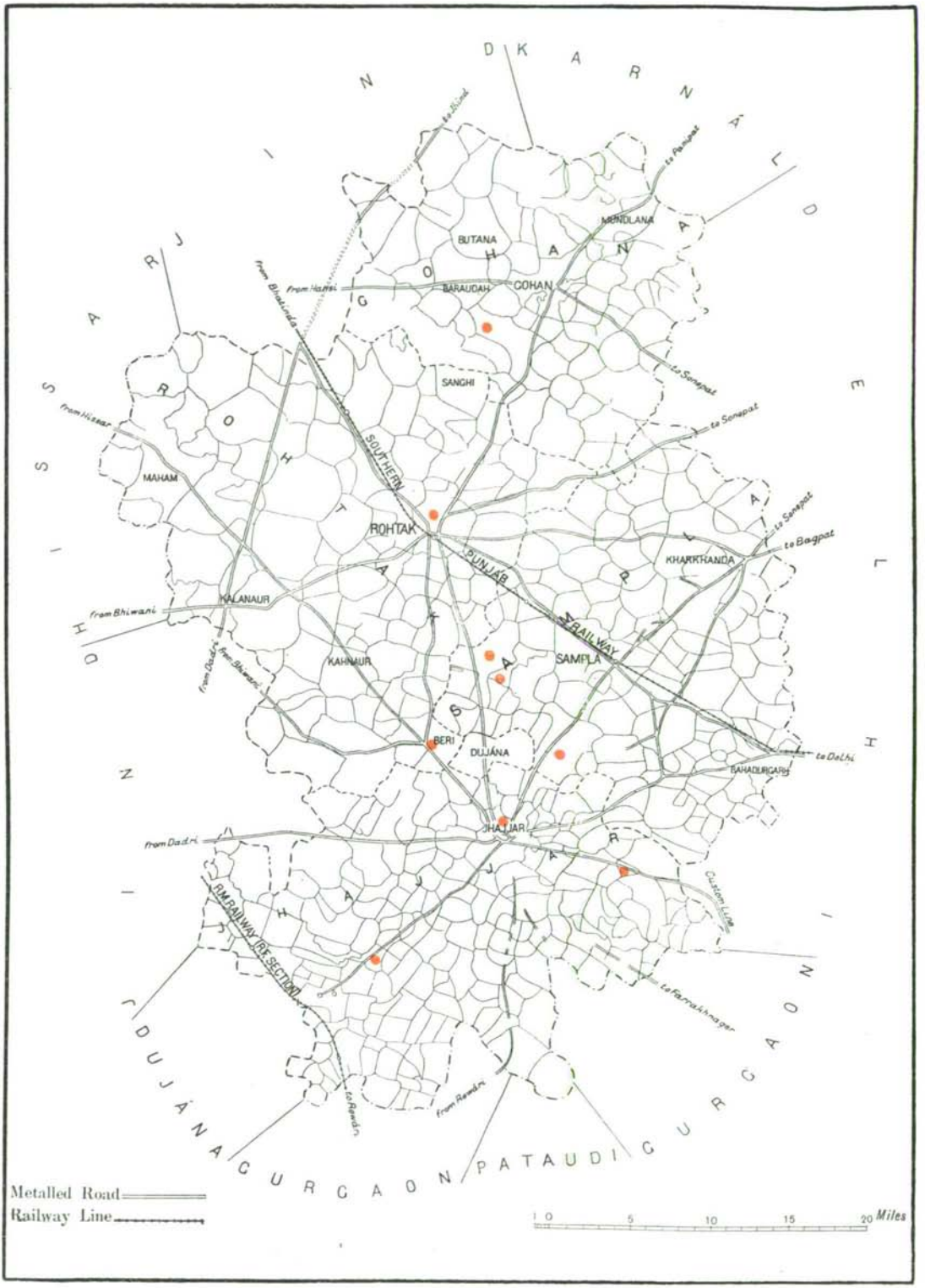


ROHTAK

September, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XVII

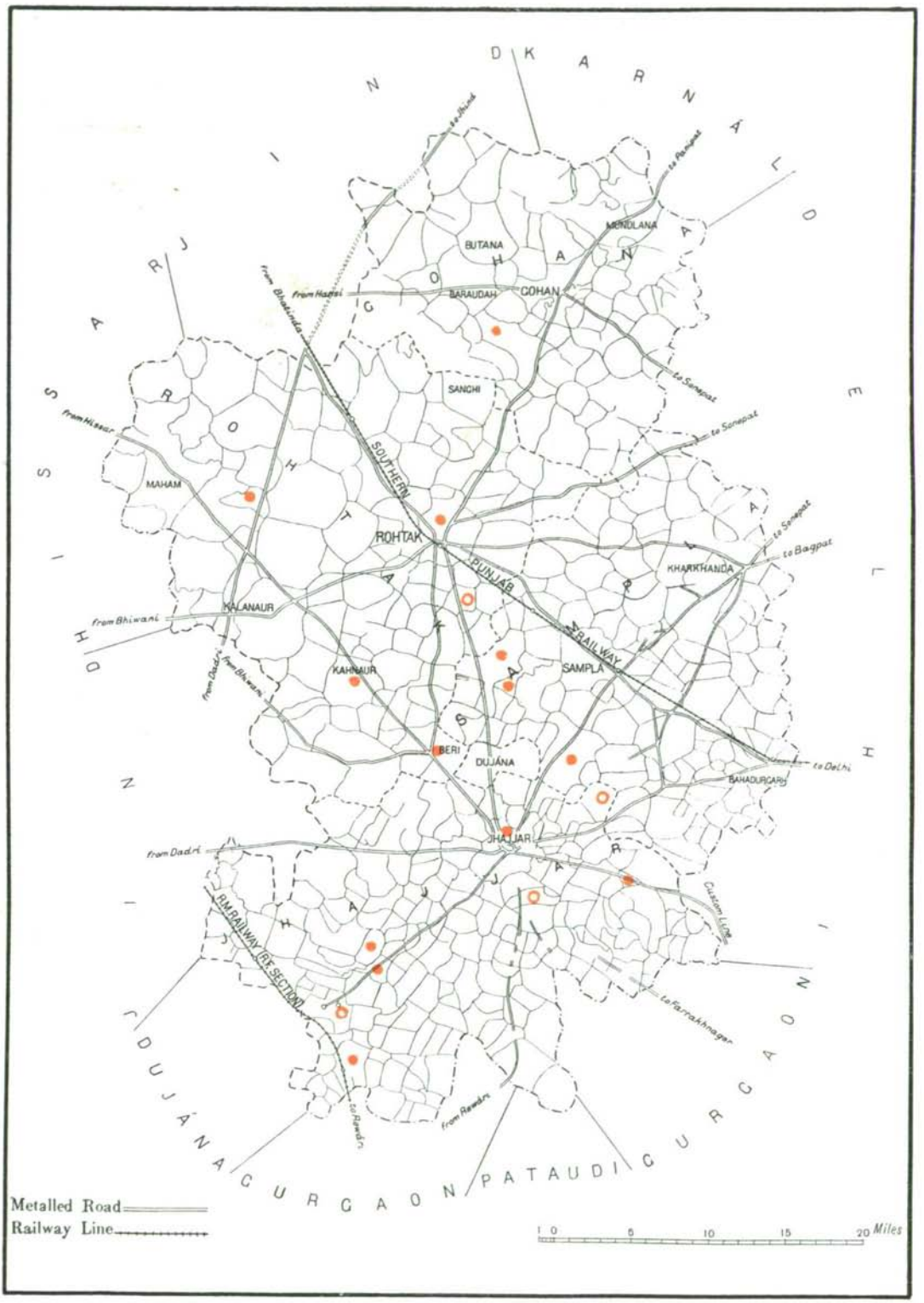


ROHTAK

October, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

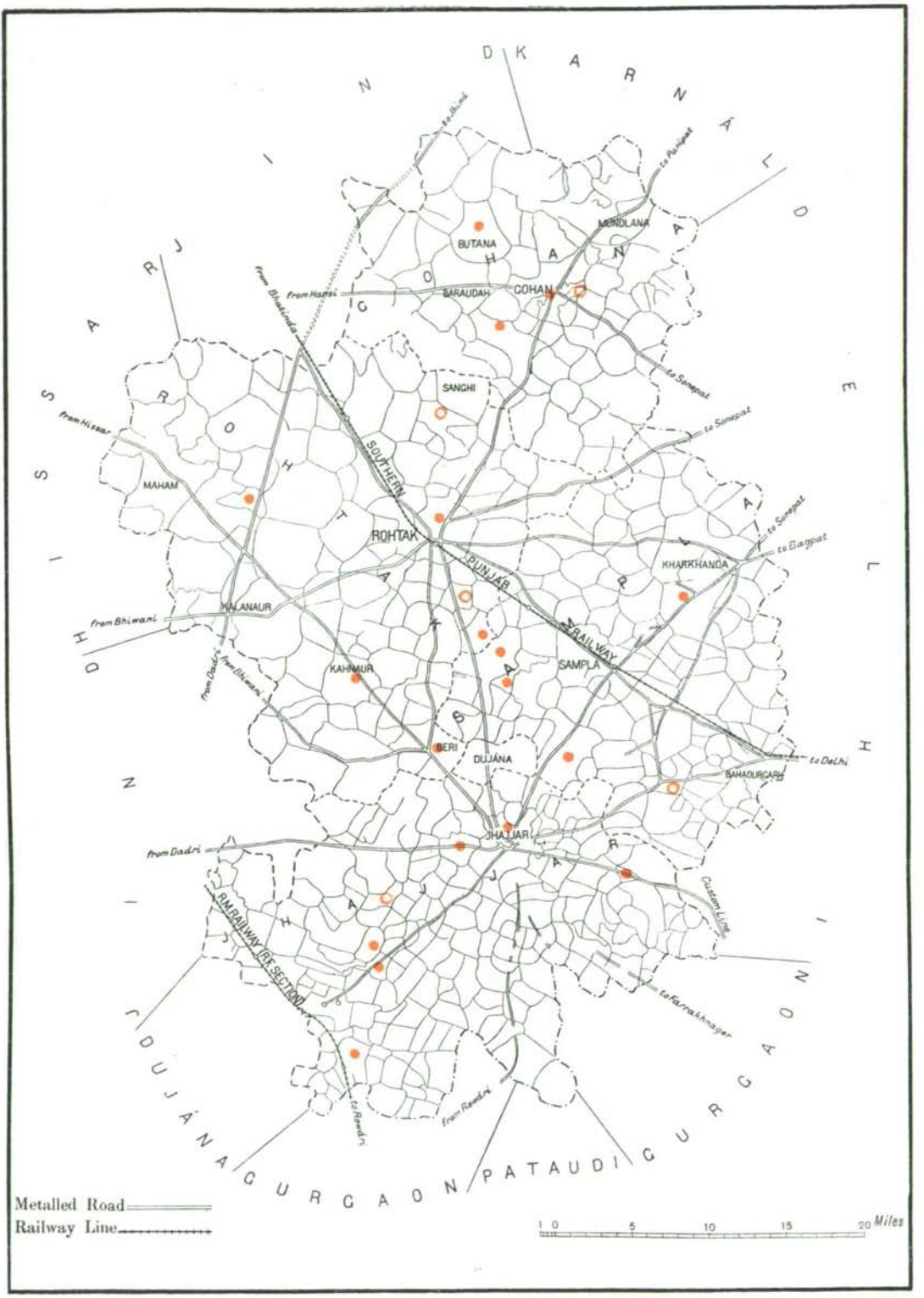
MAP XVIII



ROHTAK

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XIX

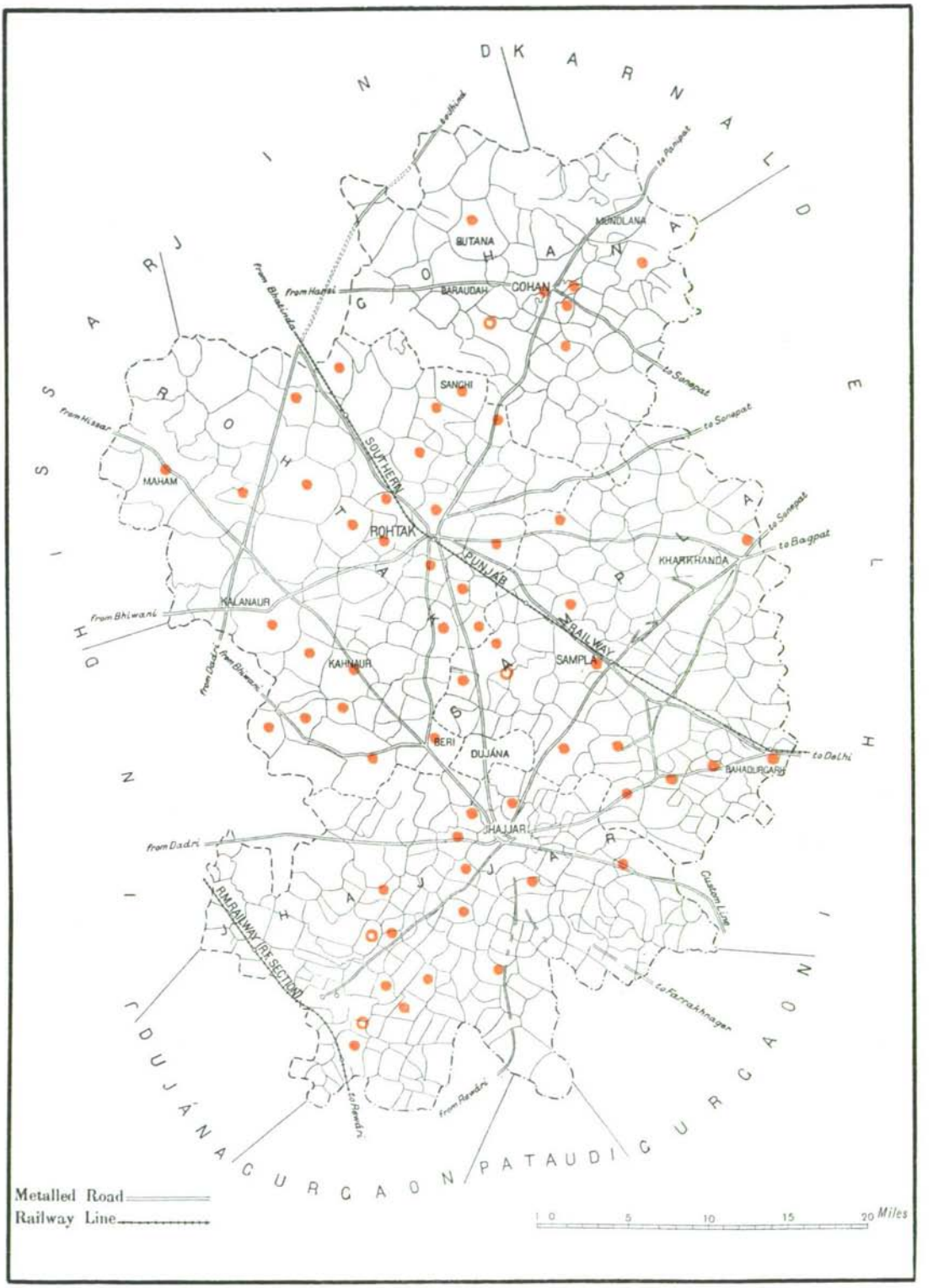


ROHTAK

December, 1904

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XX

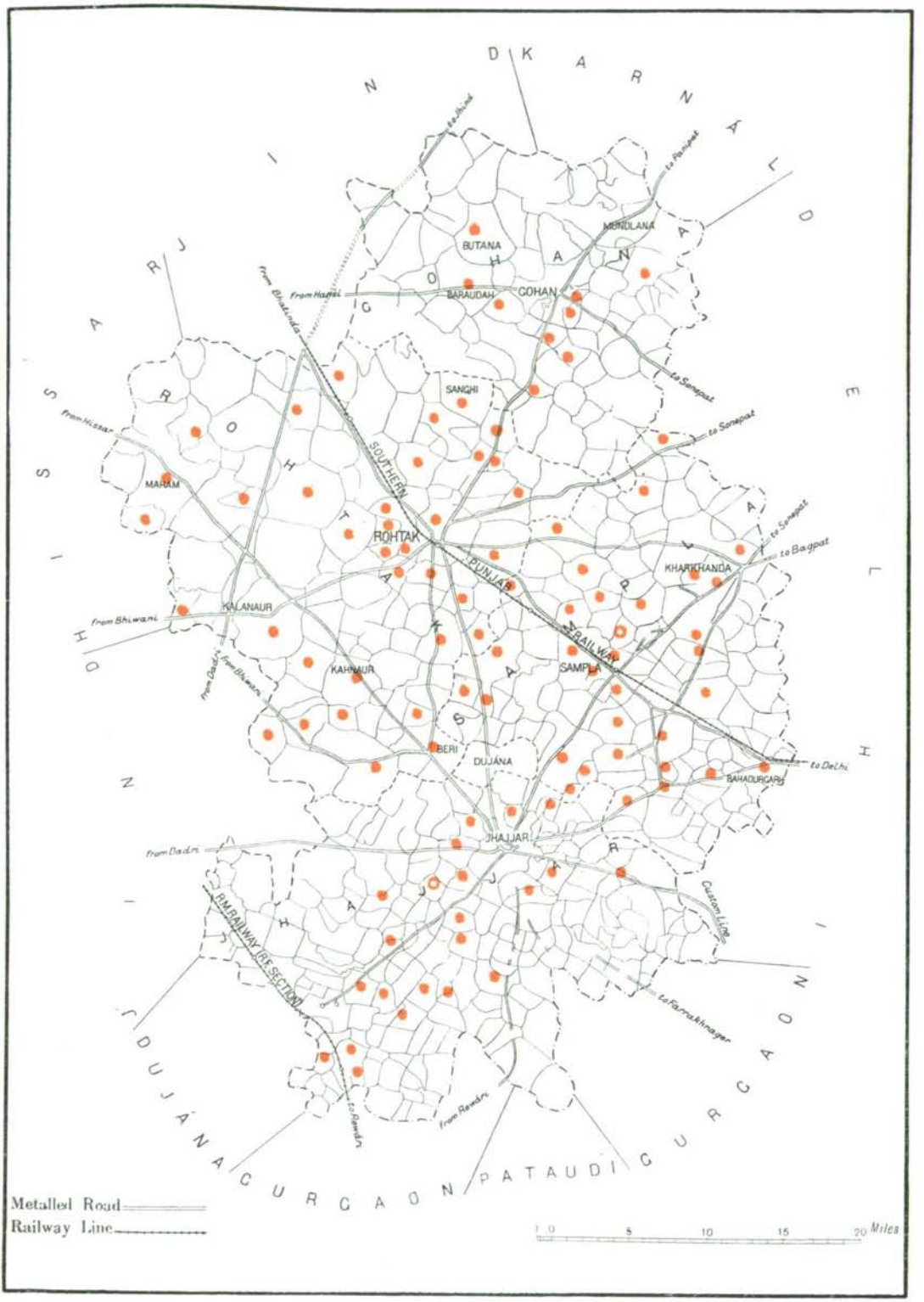


ROHTAK

January, 1905

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXI

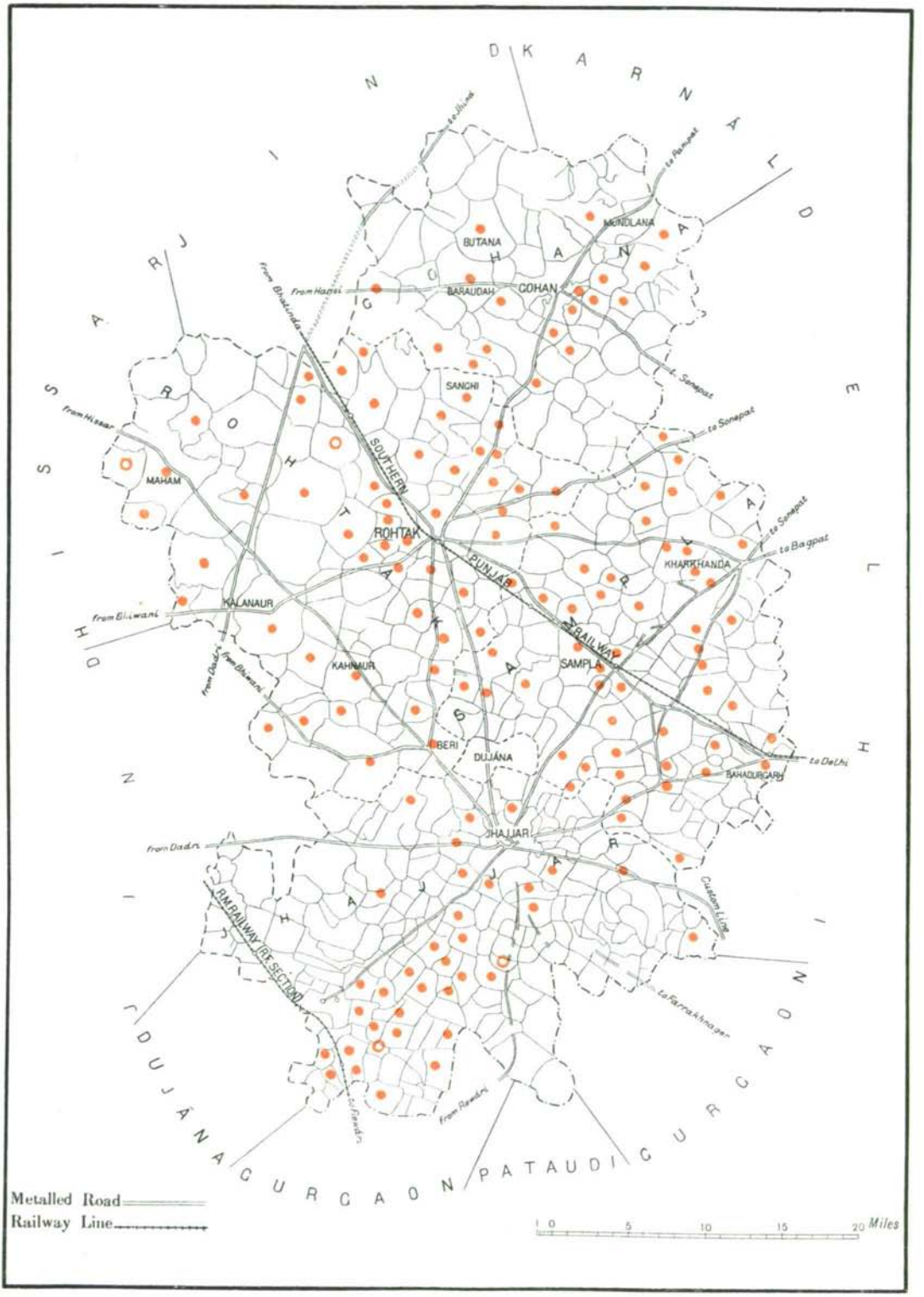


ROHTAK

February, 1905

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXII

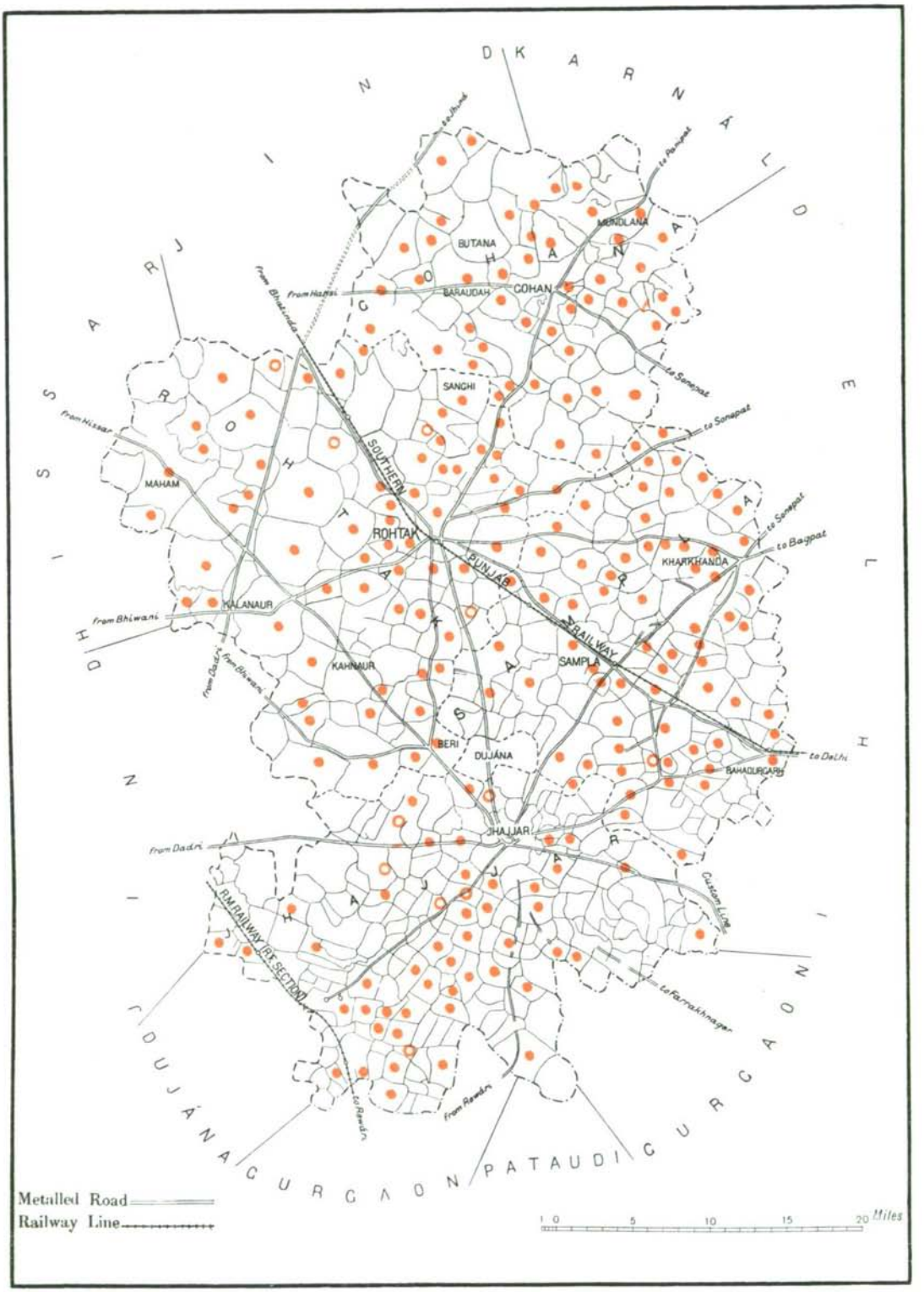


ROHTAK

March, 1905

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXIII

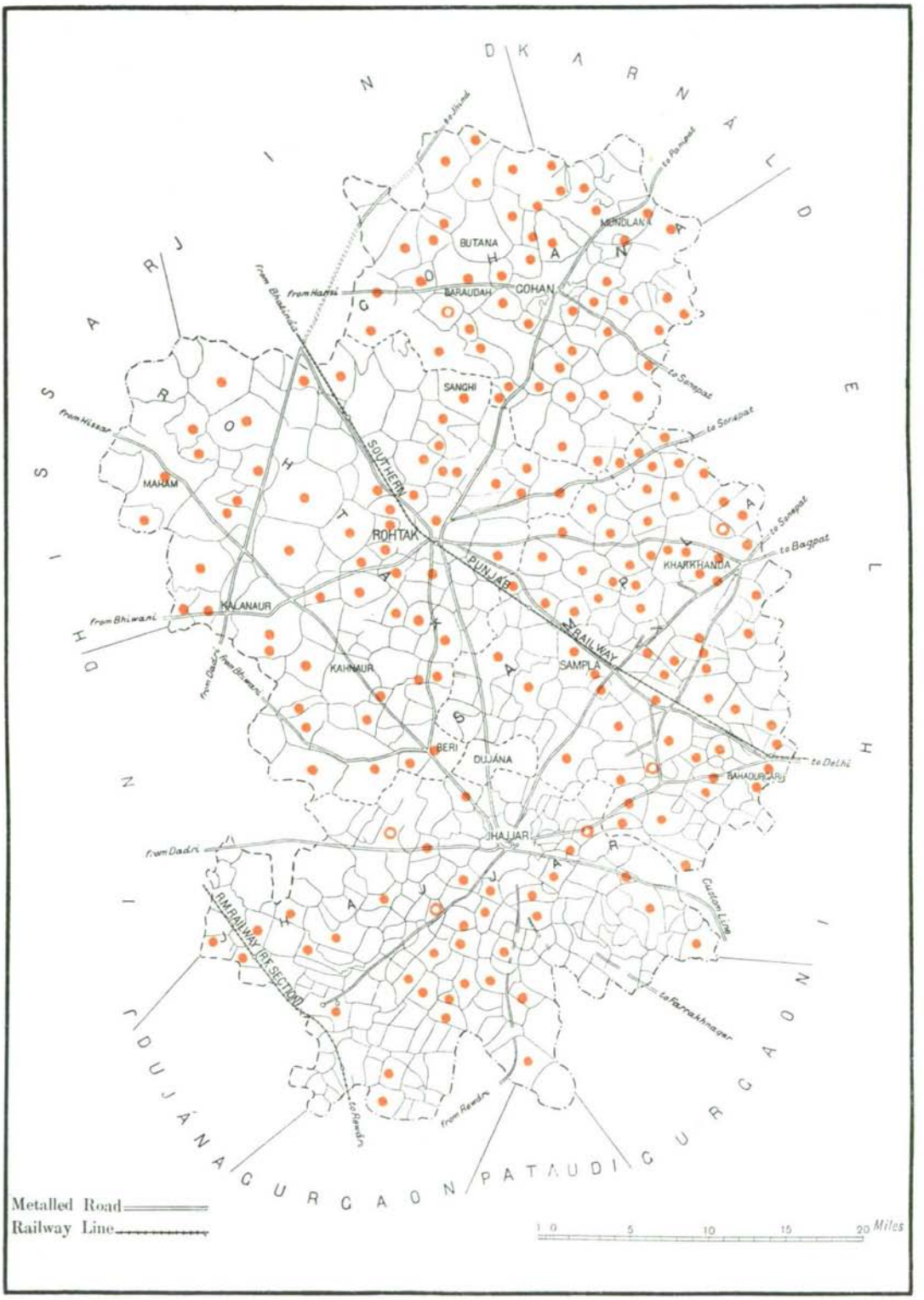


ROHTAK

April, 1905

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

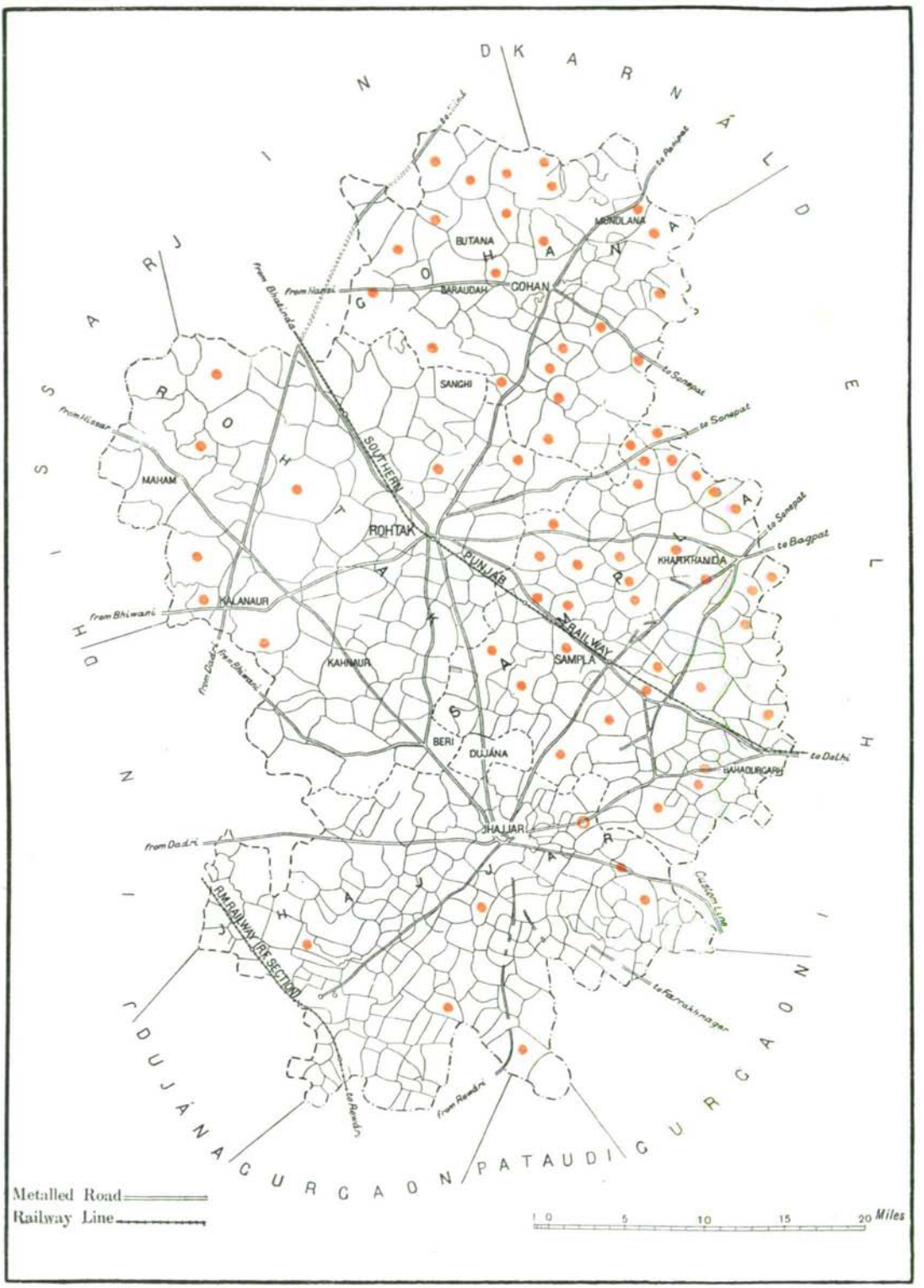
MAP XXIV



ROHTAK

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXV

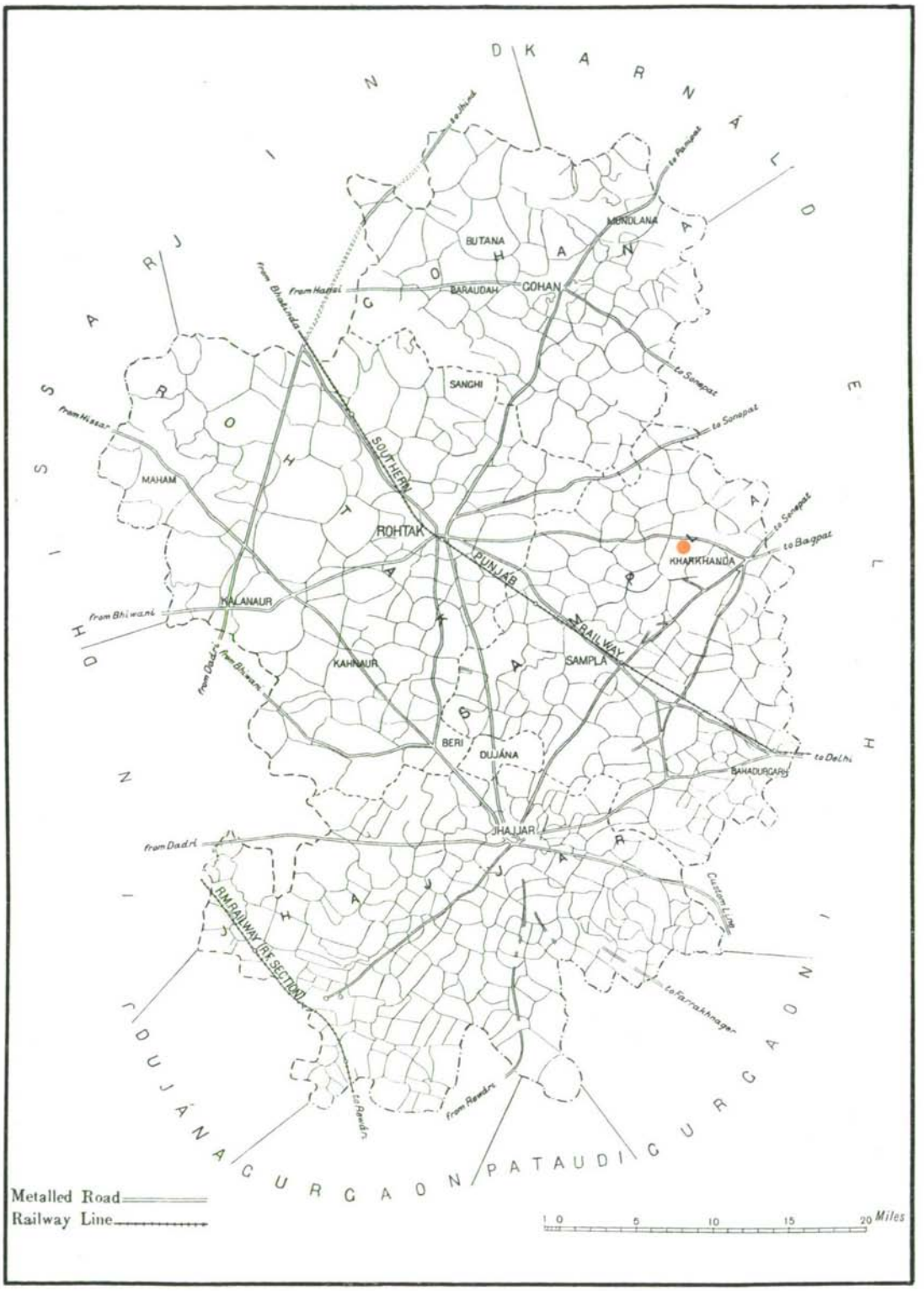


ROHTAK

June, 1905

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXVI

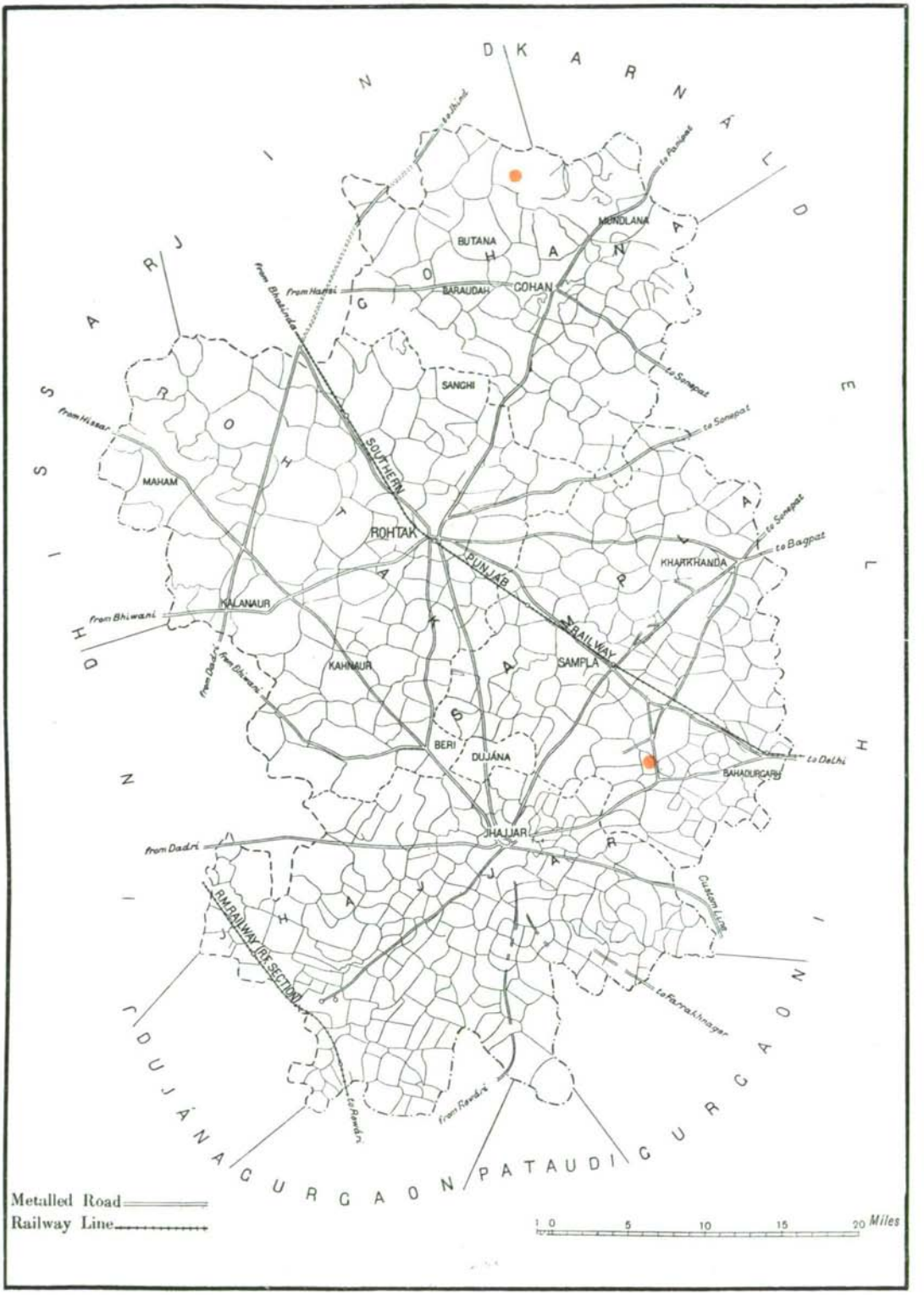


ROHTAK

July, 1905

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXVII

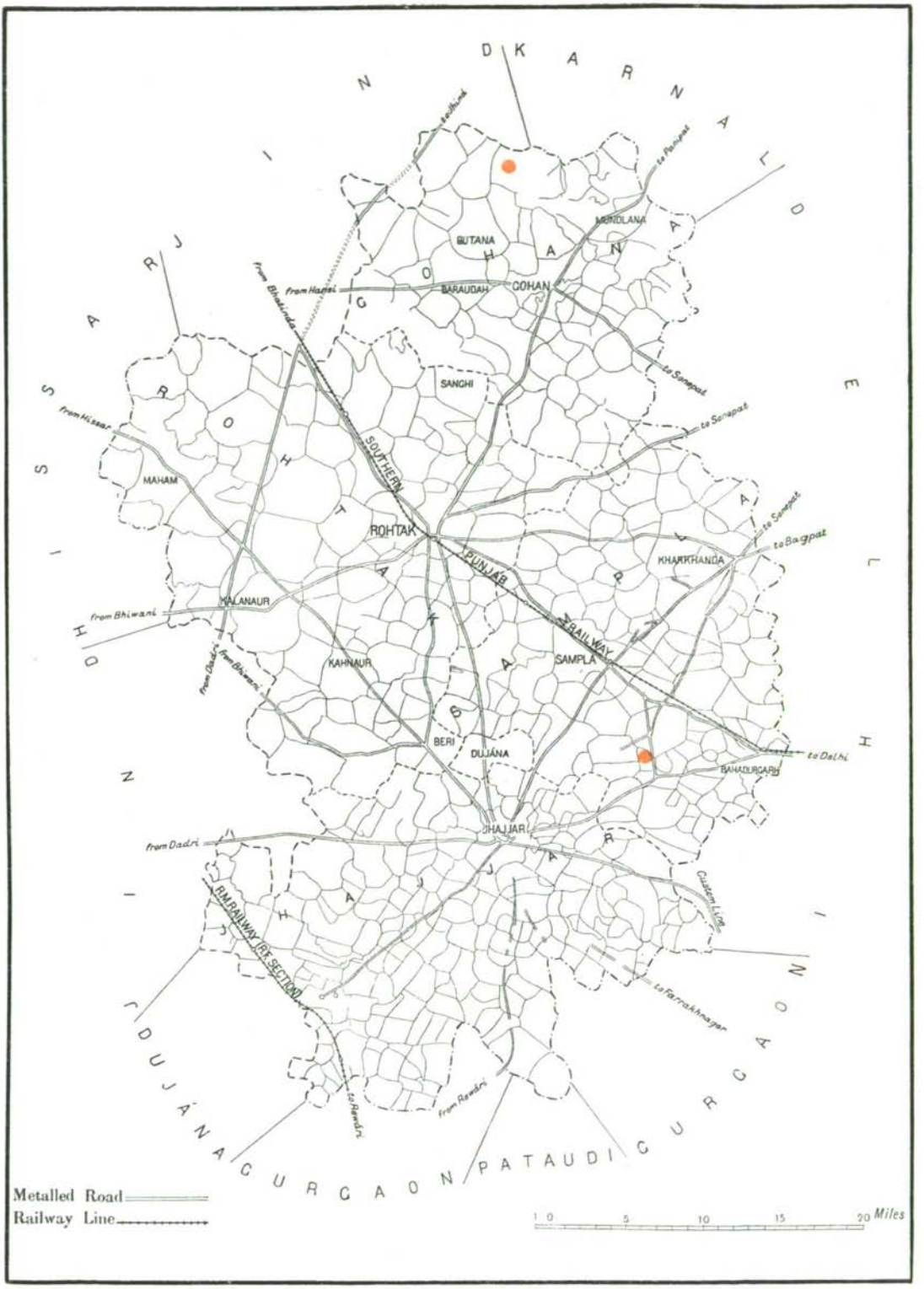


ROHTAK

October, 1905

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXVIII

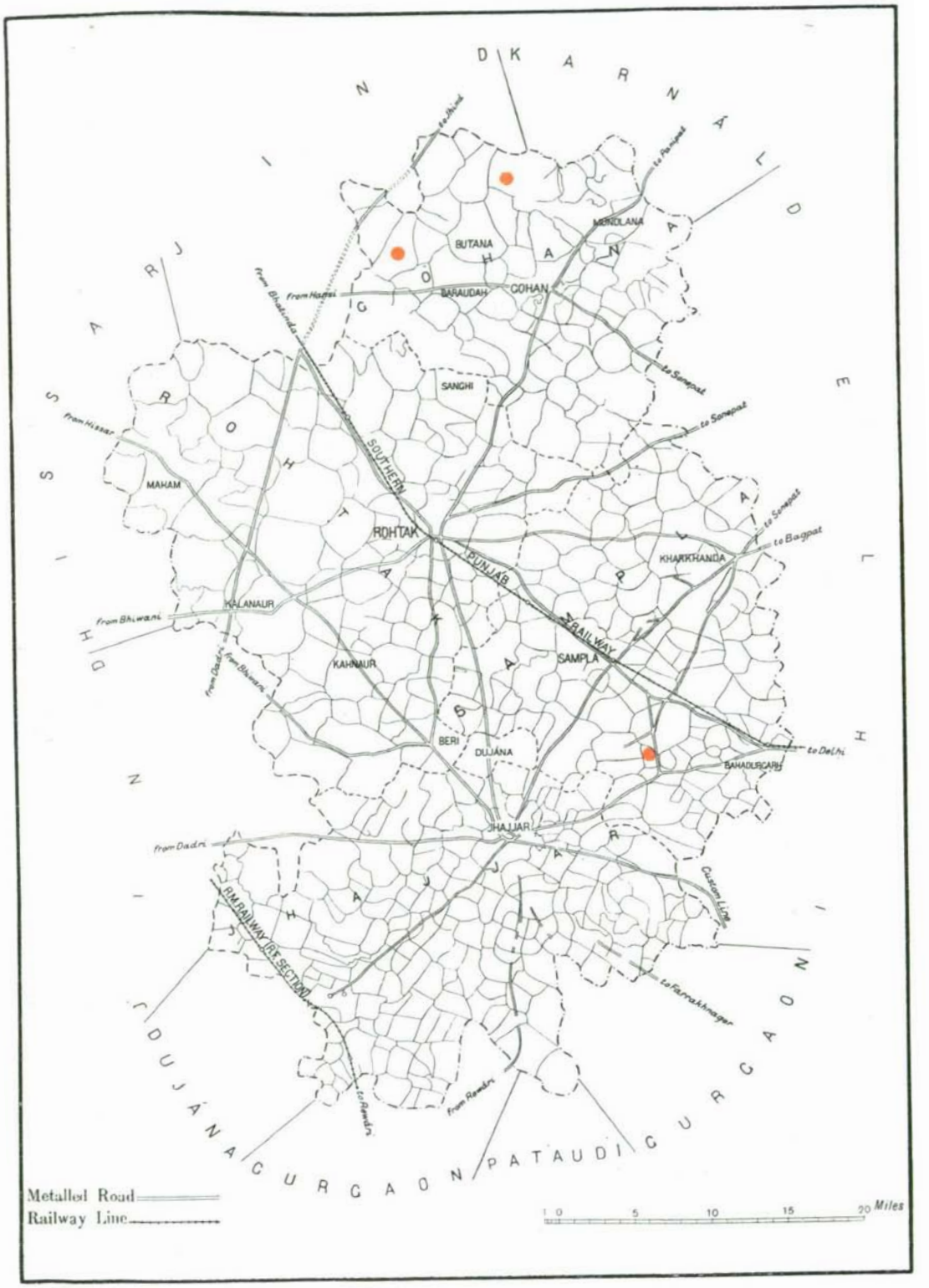


ROHTAK

November, 1905

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

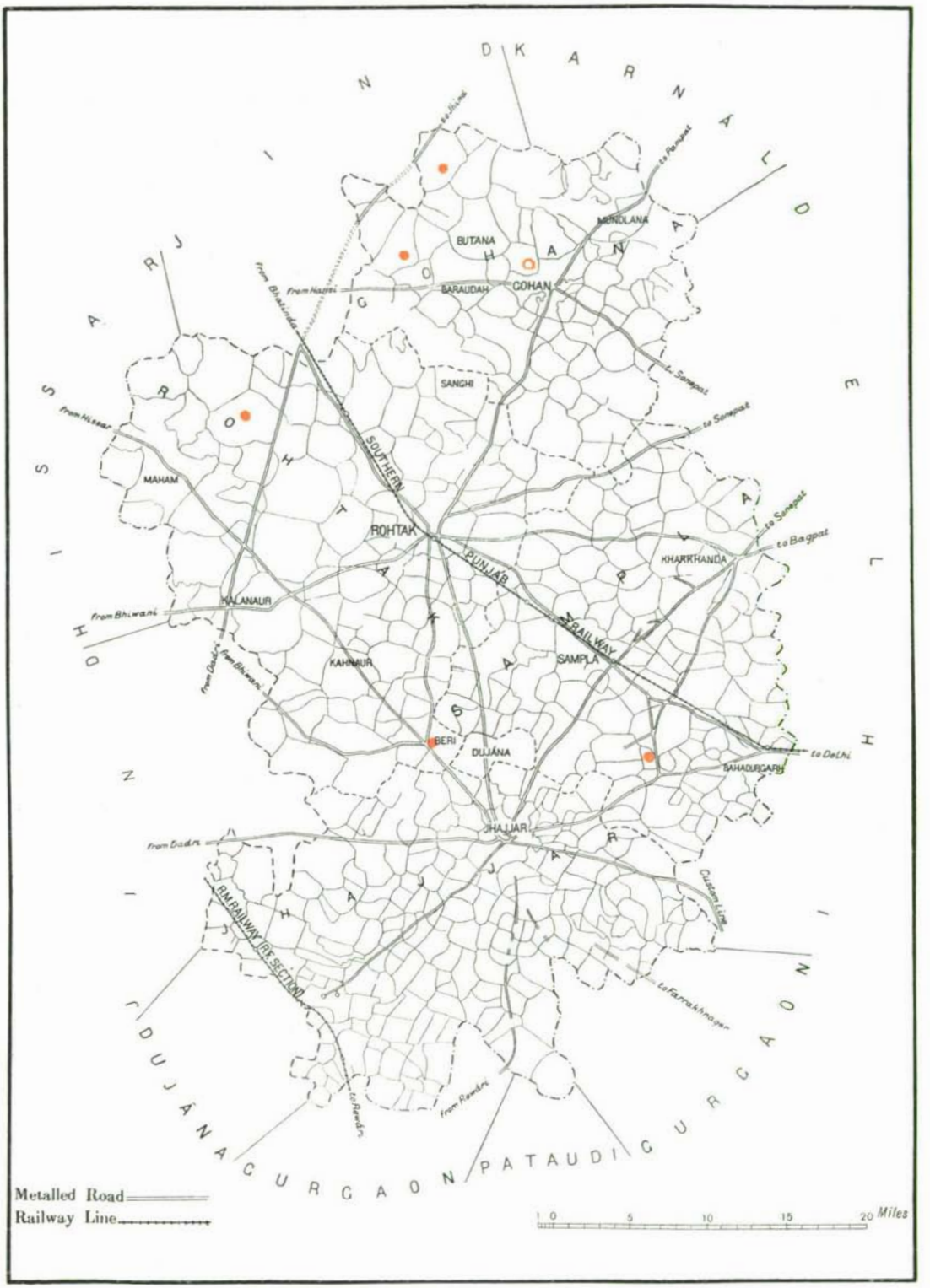
MAP XXIX



ROHTAK

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXX

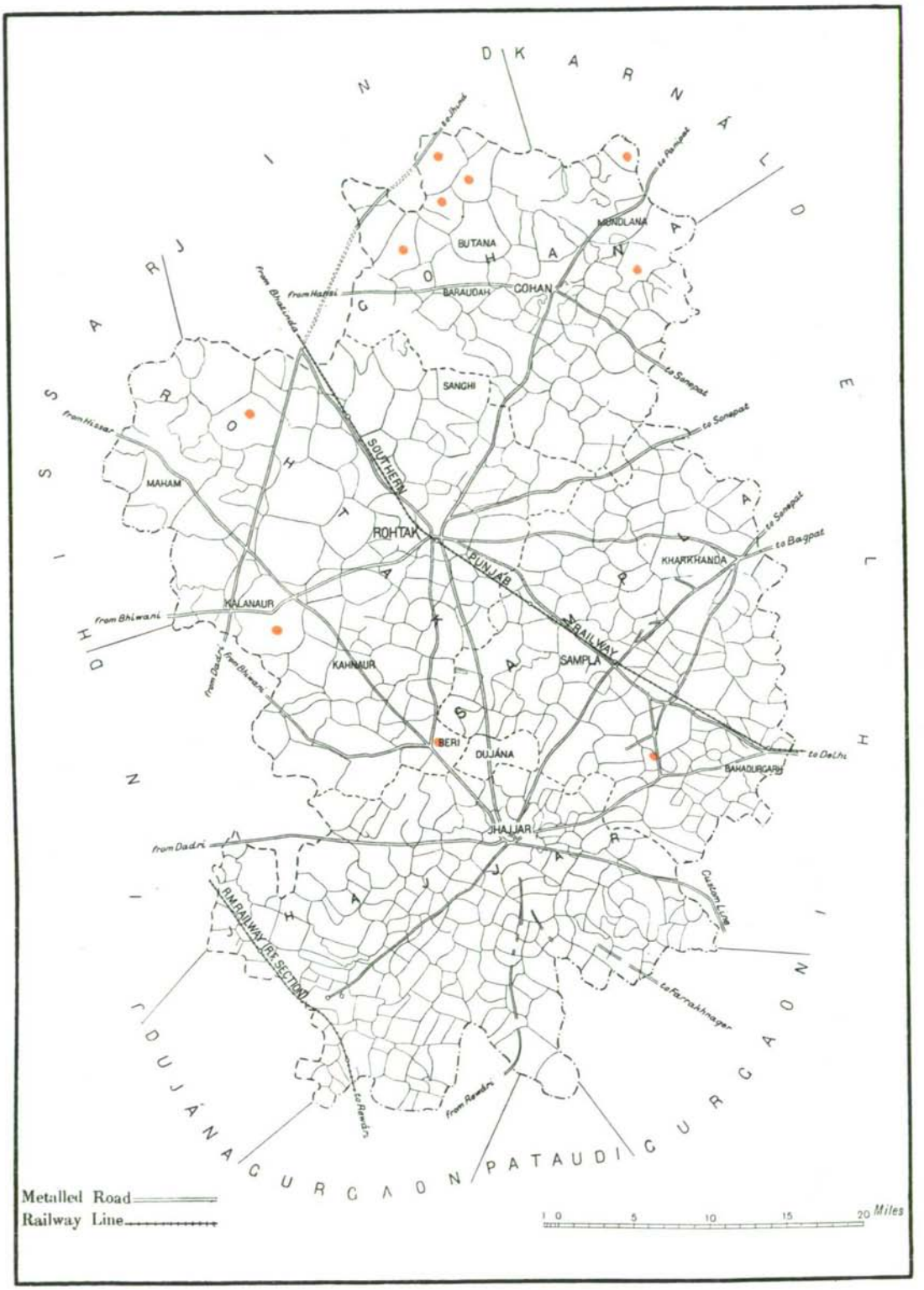


ROHTAK

January, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXXI

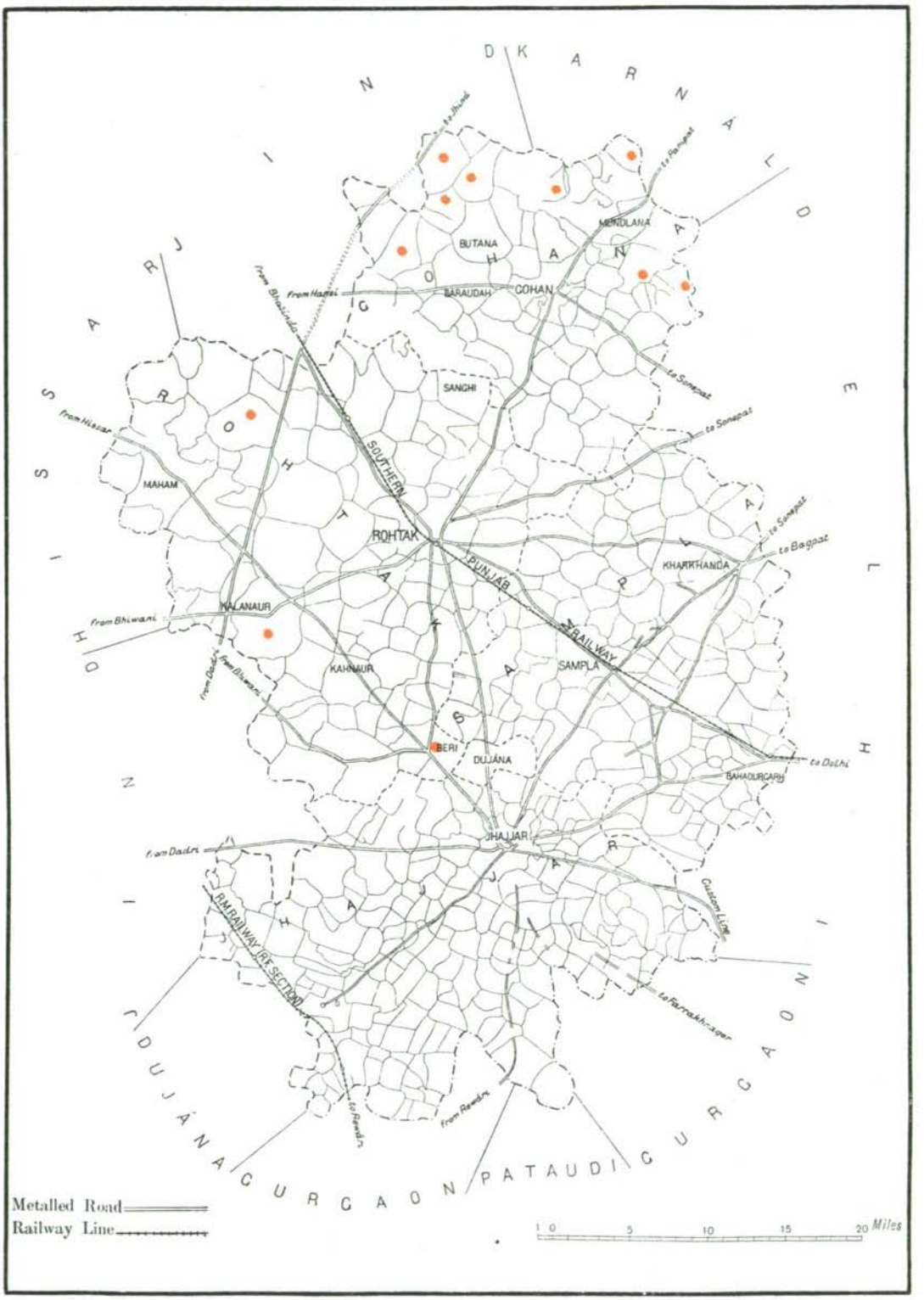


ROHTAK

February, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXXII

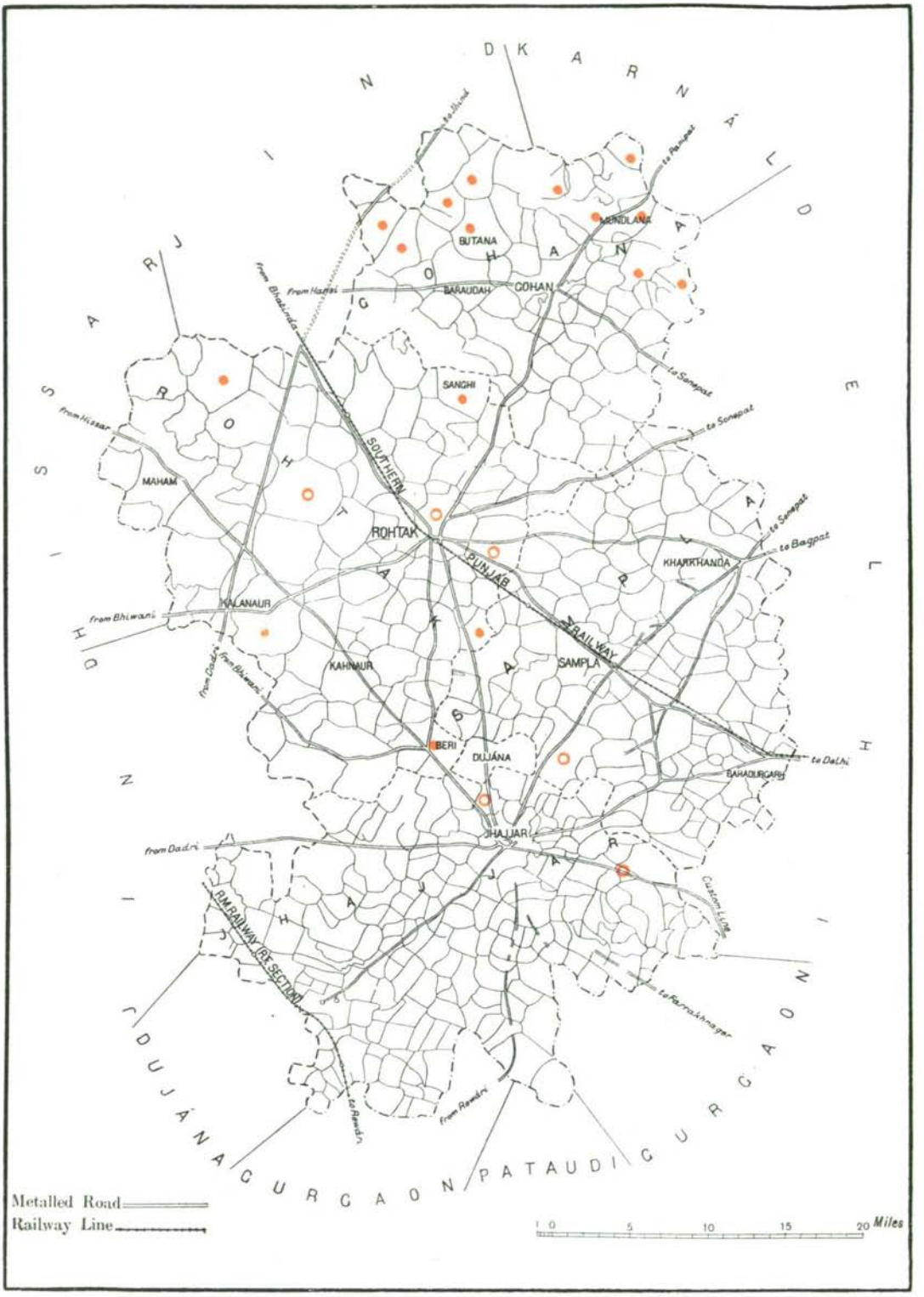


ROHTAK

March, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXXIII

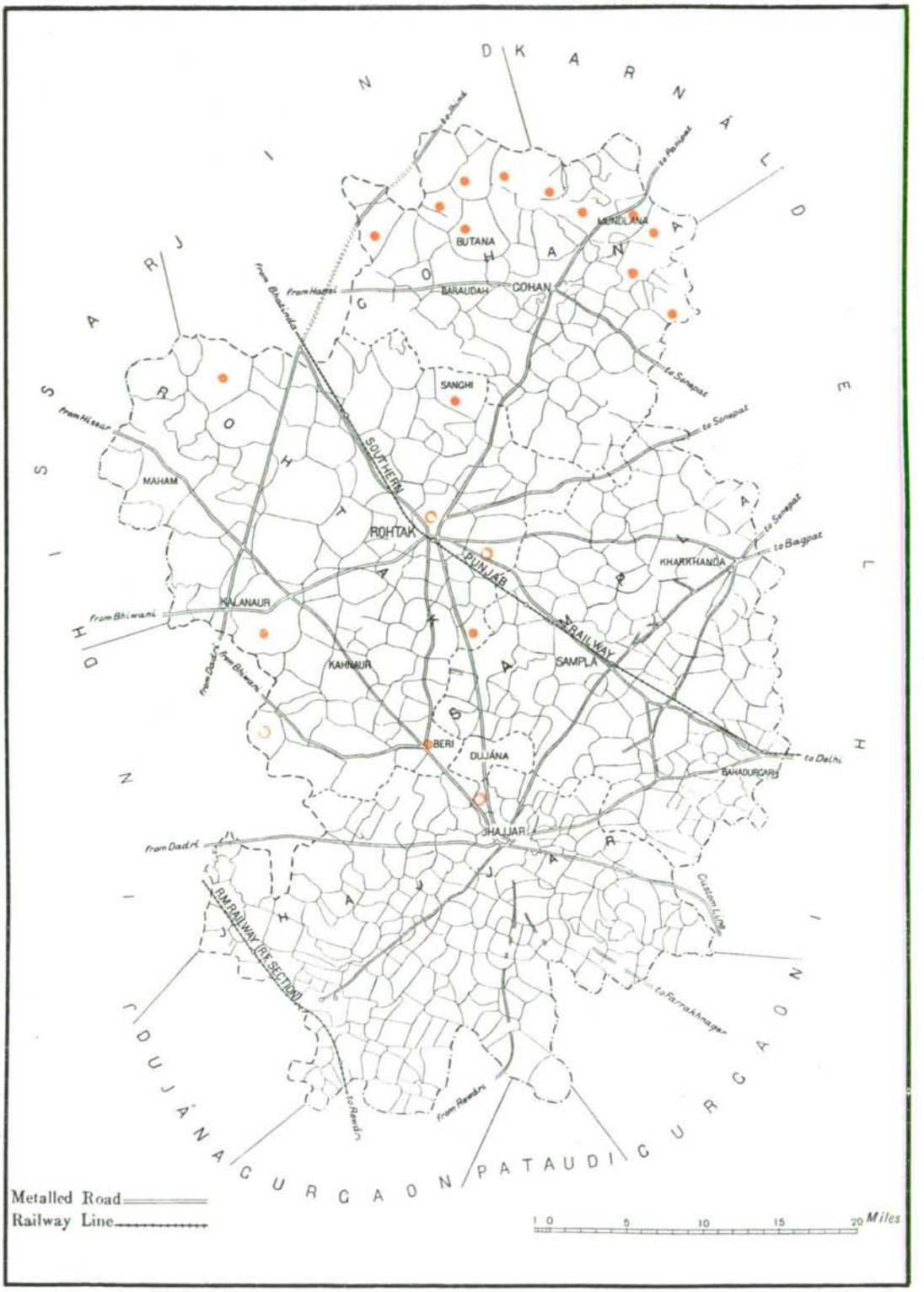


ROHTAK

April, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXXIV

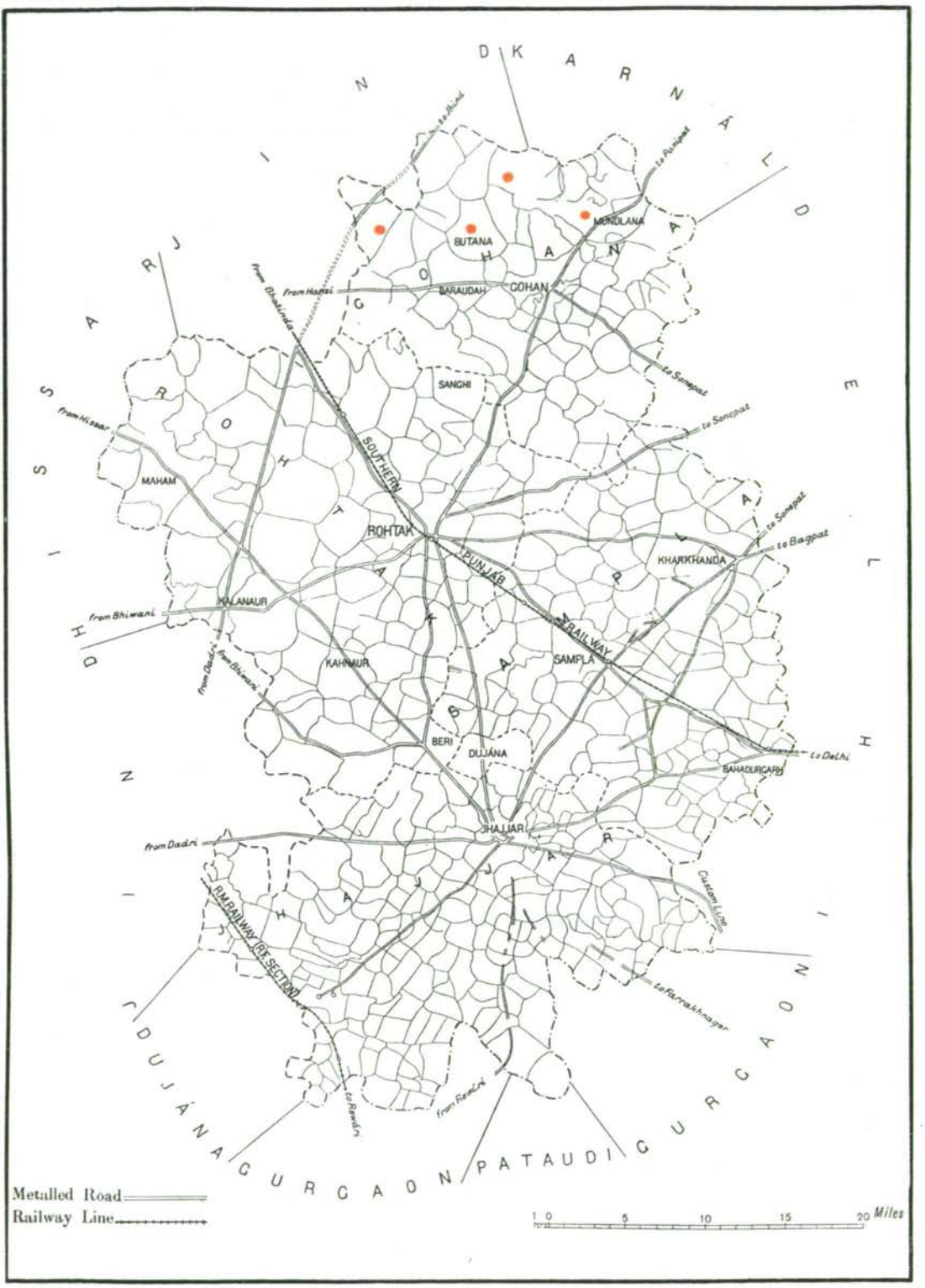


ROHTAK

May, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXXV

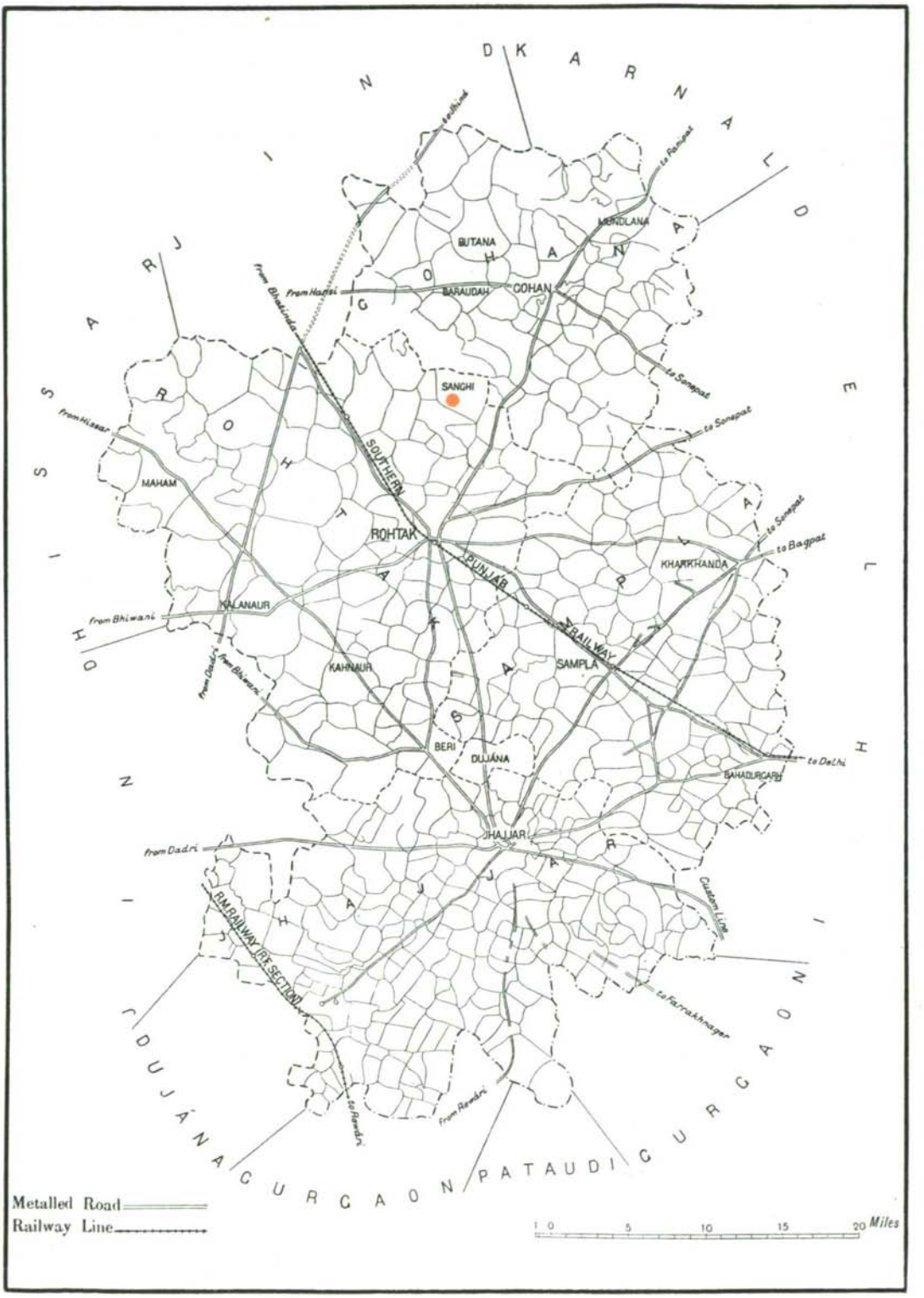


ROHTAK

June, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXXVI

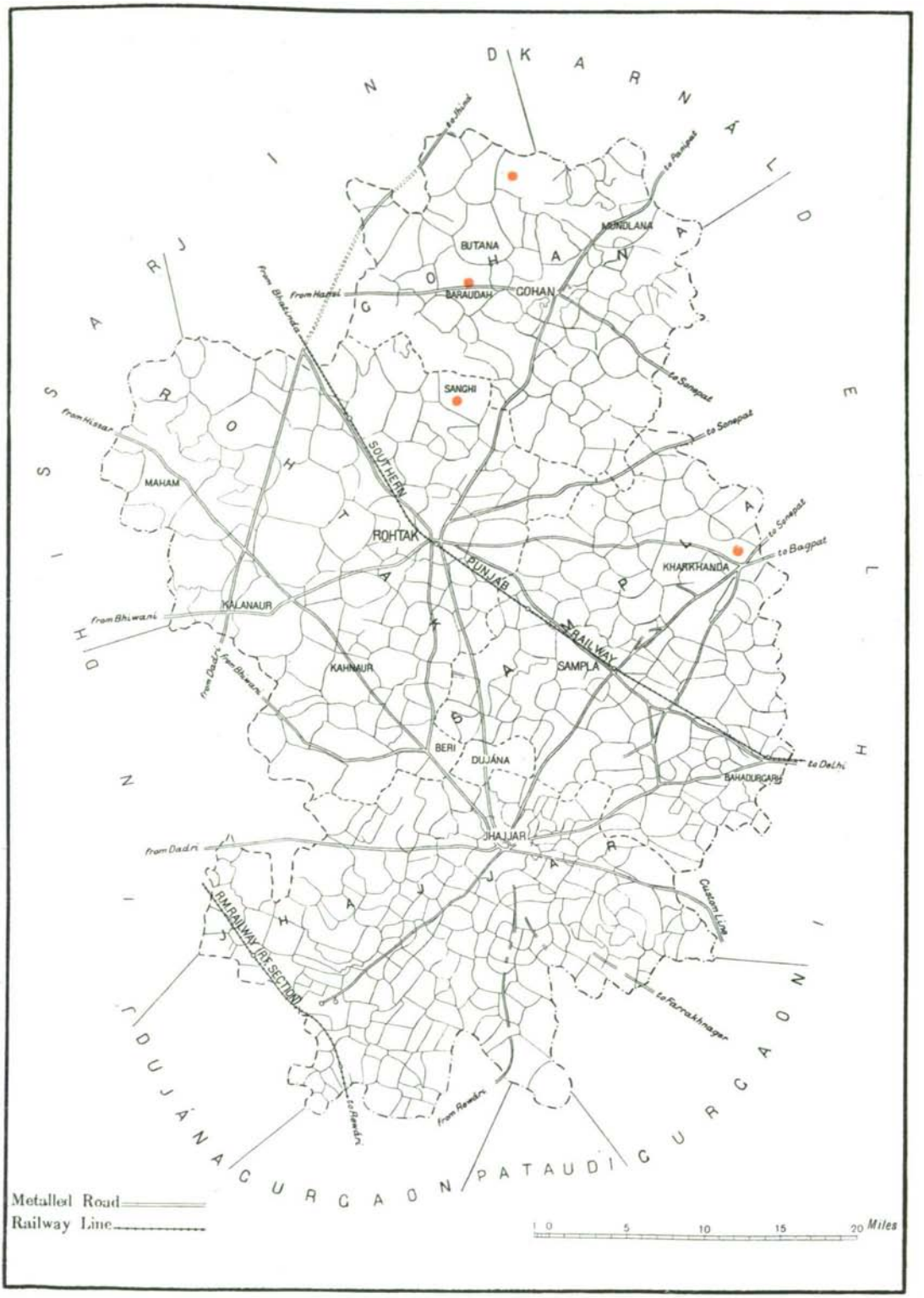


ROHTAK

August, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XXXVII

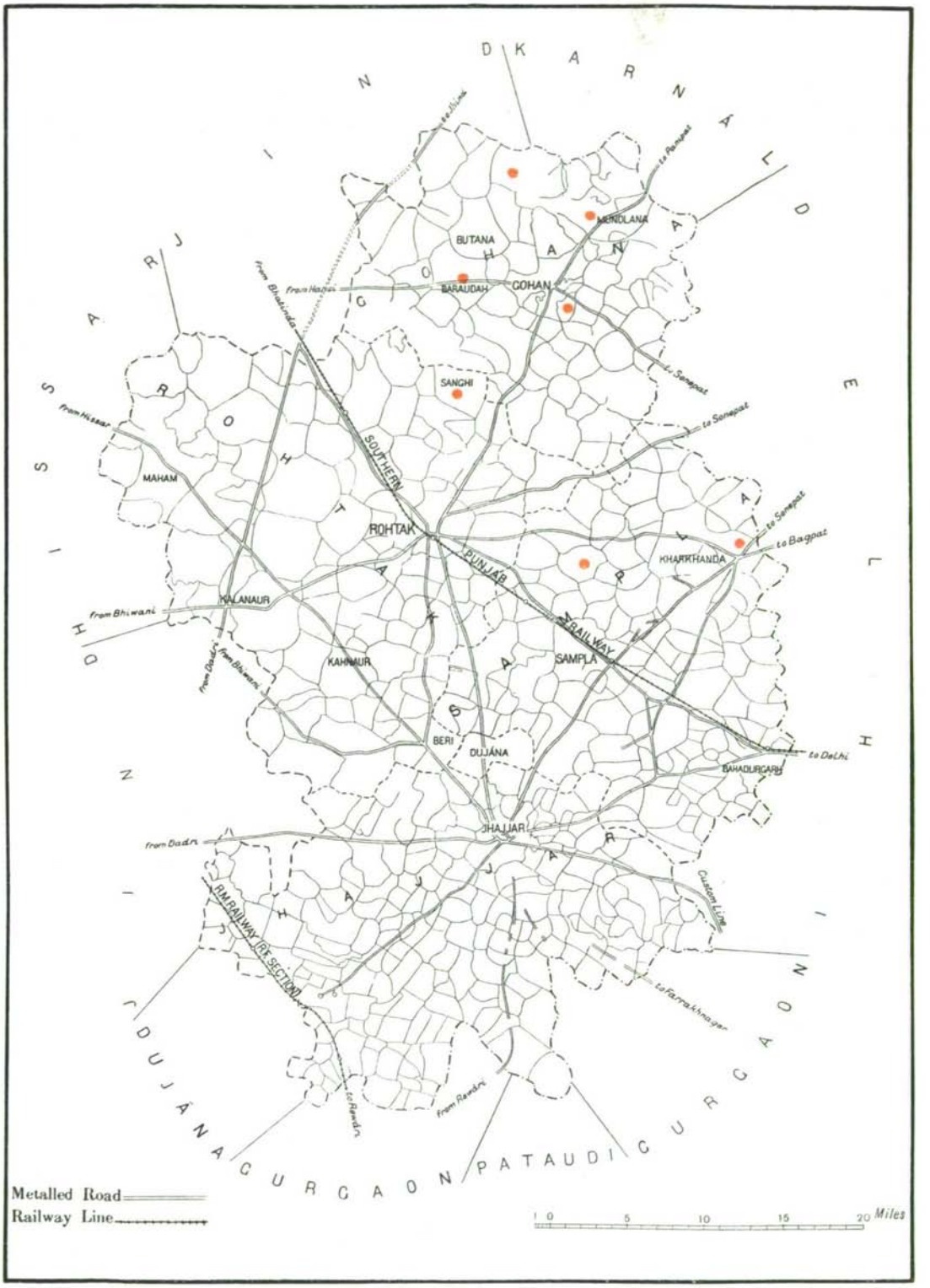


ROHTAK

September, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

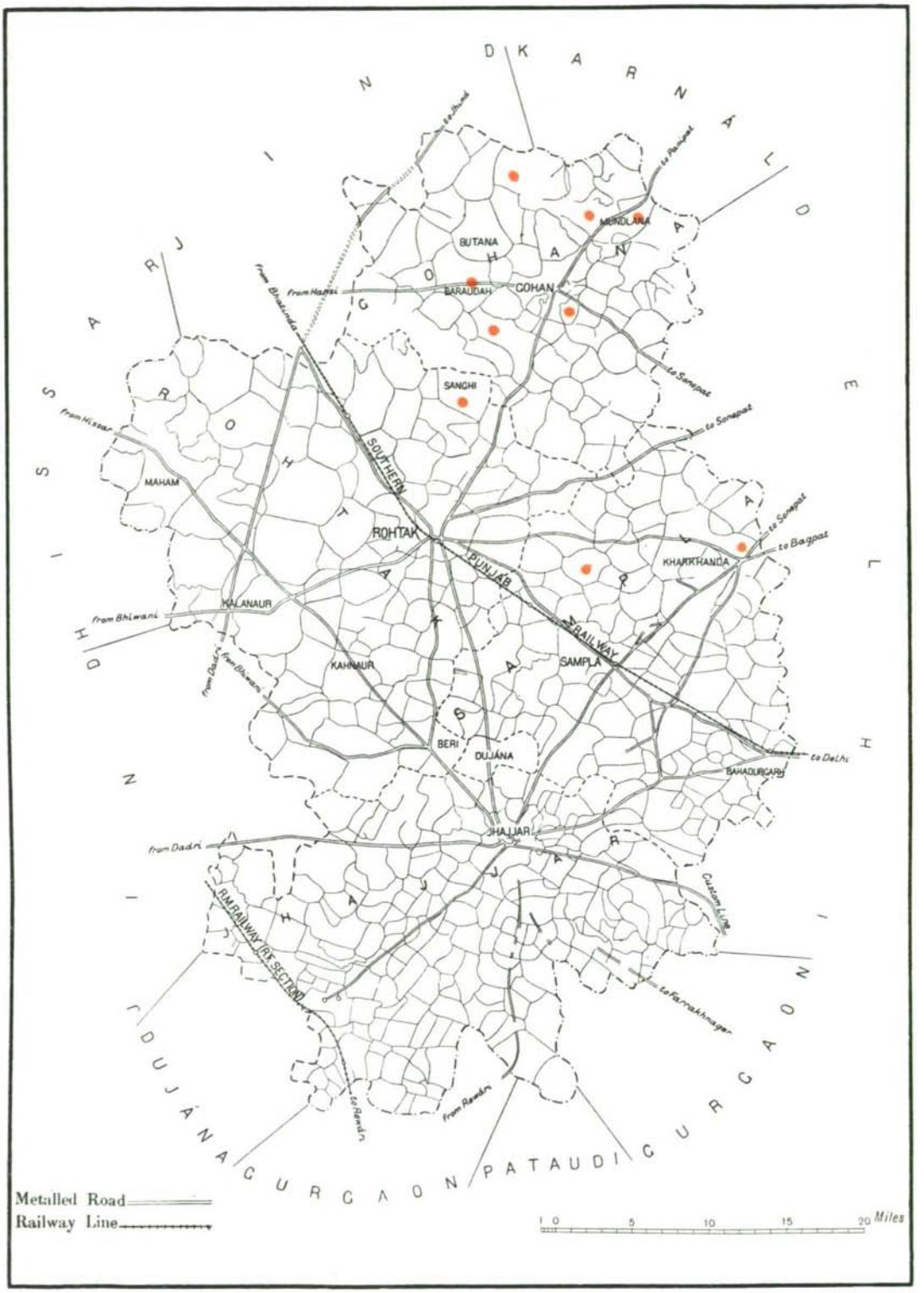
MAP XXXVIII



ROHTAK

October, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

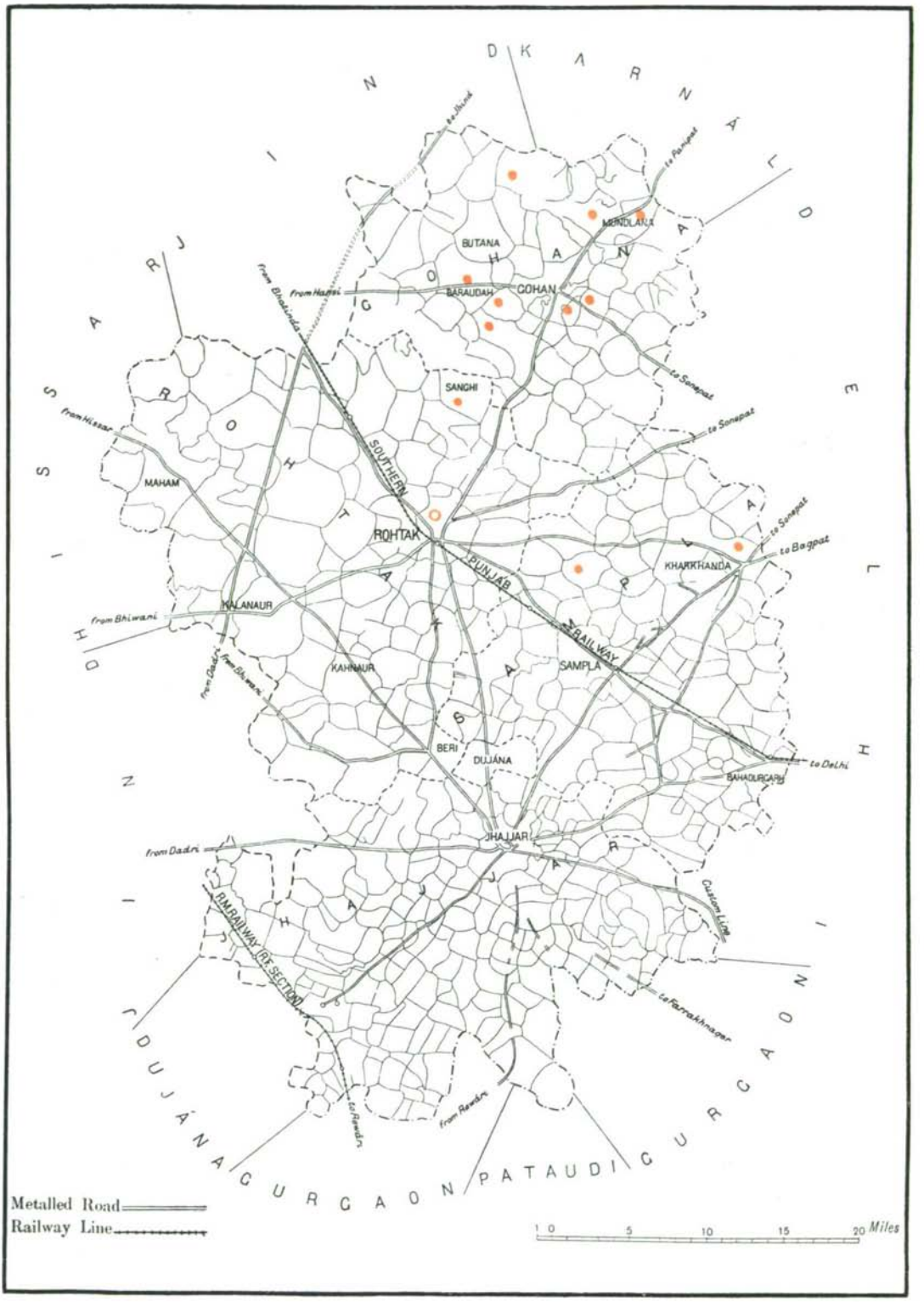


ROHTAK

November, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XL

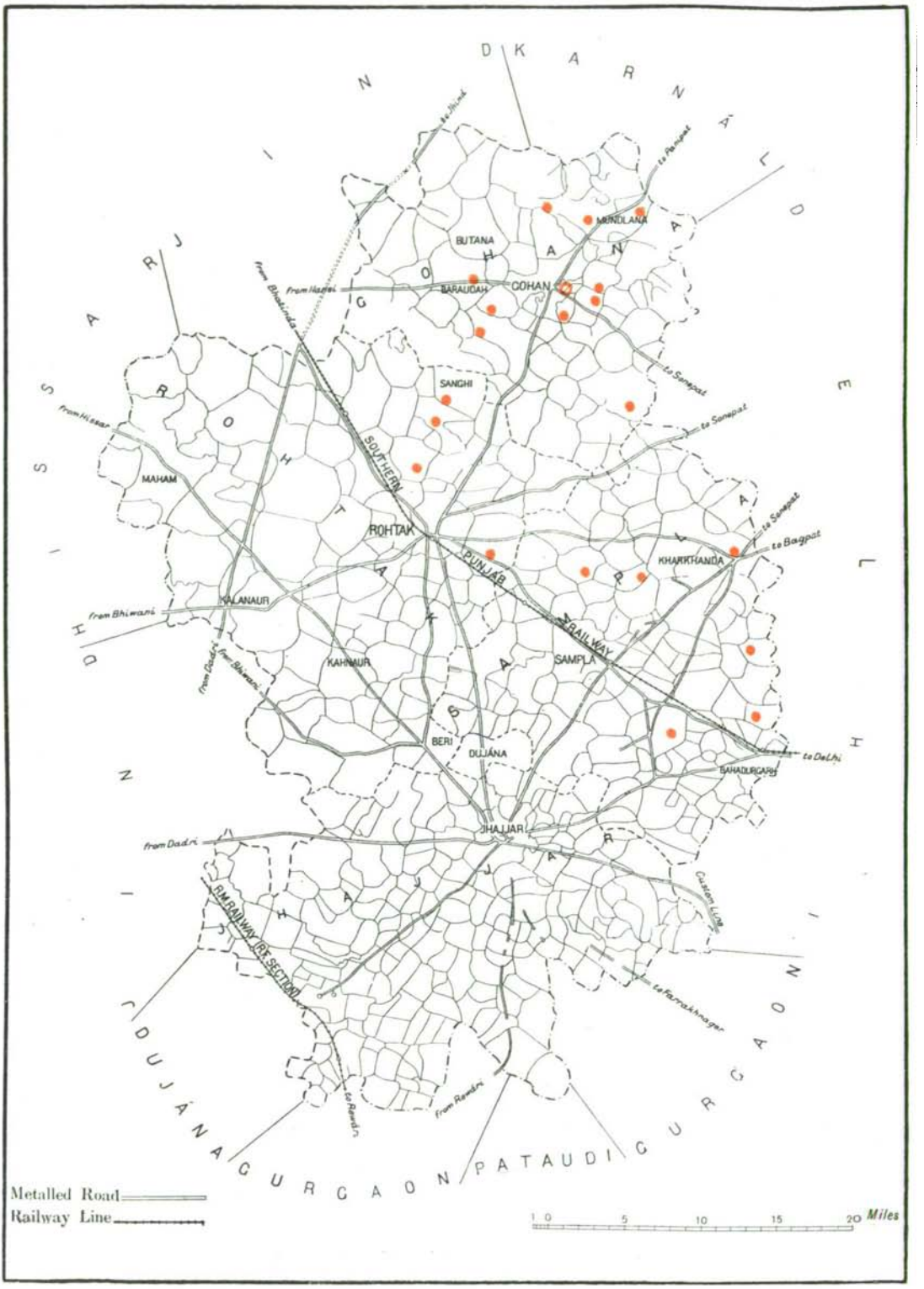


ROHTAK

December, 1906

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XLI

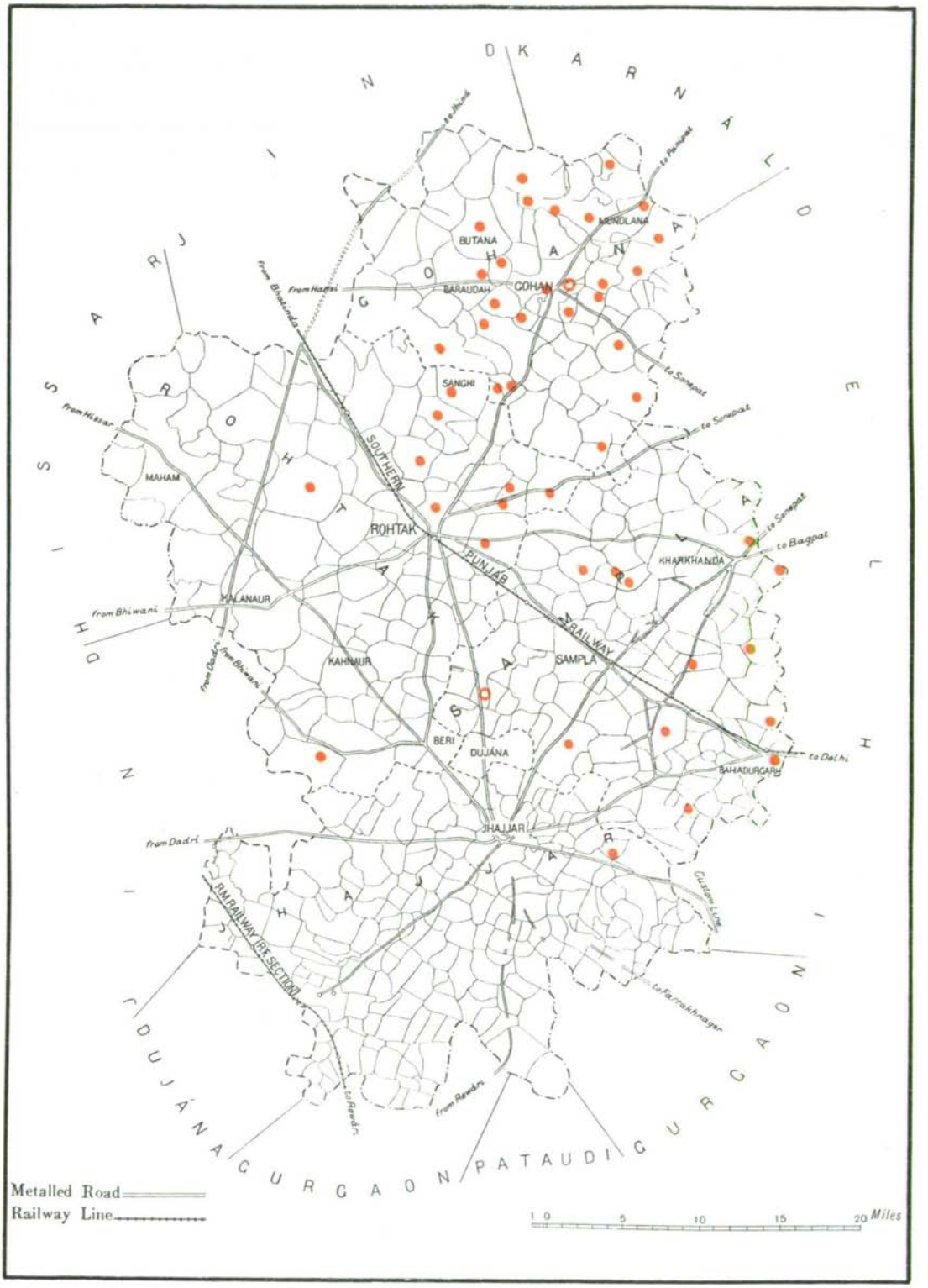


ROHTAK

January, 1907

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XLII

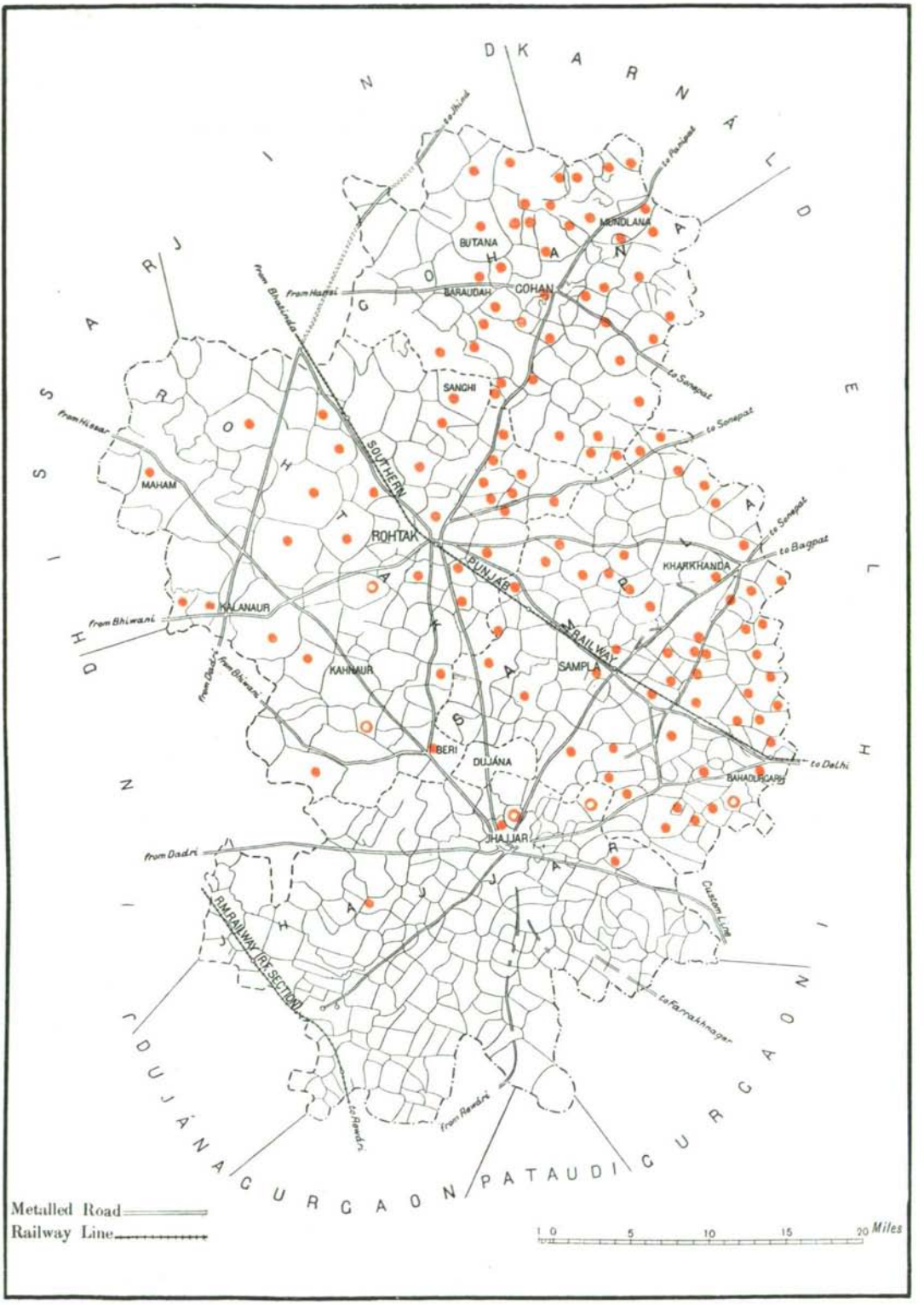


ROHTAK

February, 1907

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XLIII

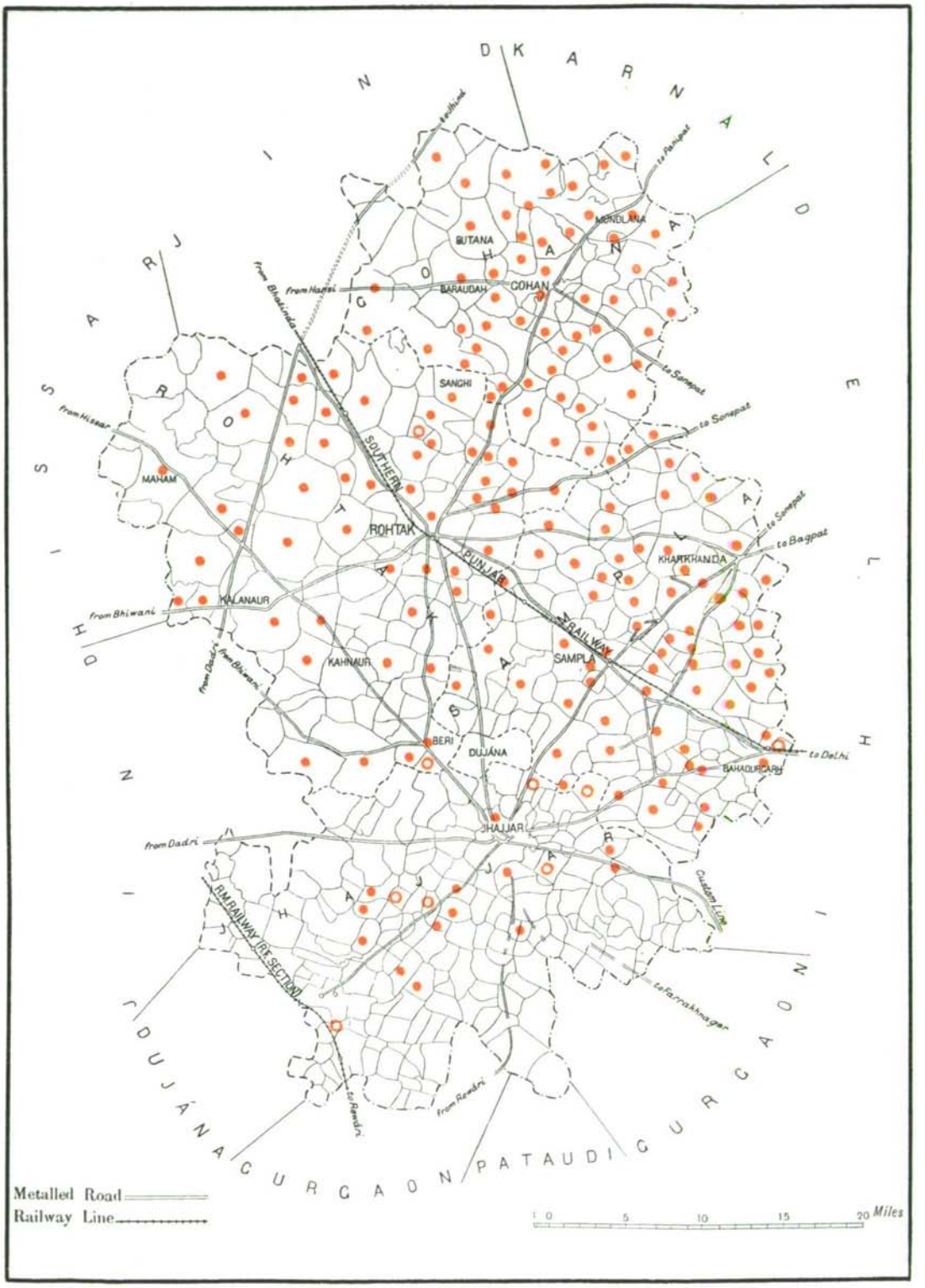


ROHTAK

March, 1907

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XLIV

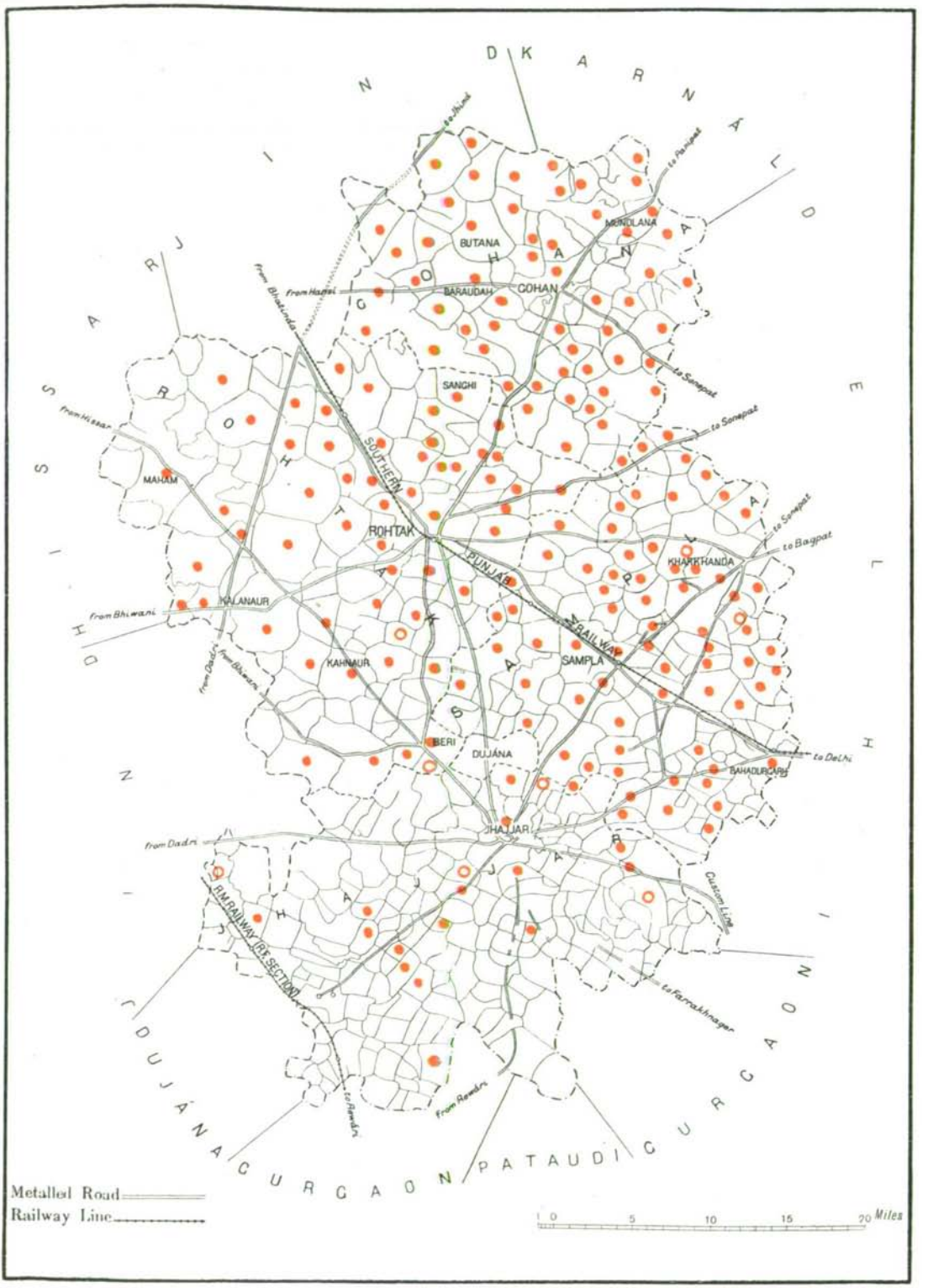


ROHTAK

April, 1907

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XLV

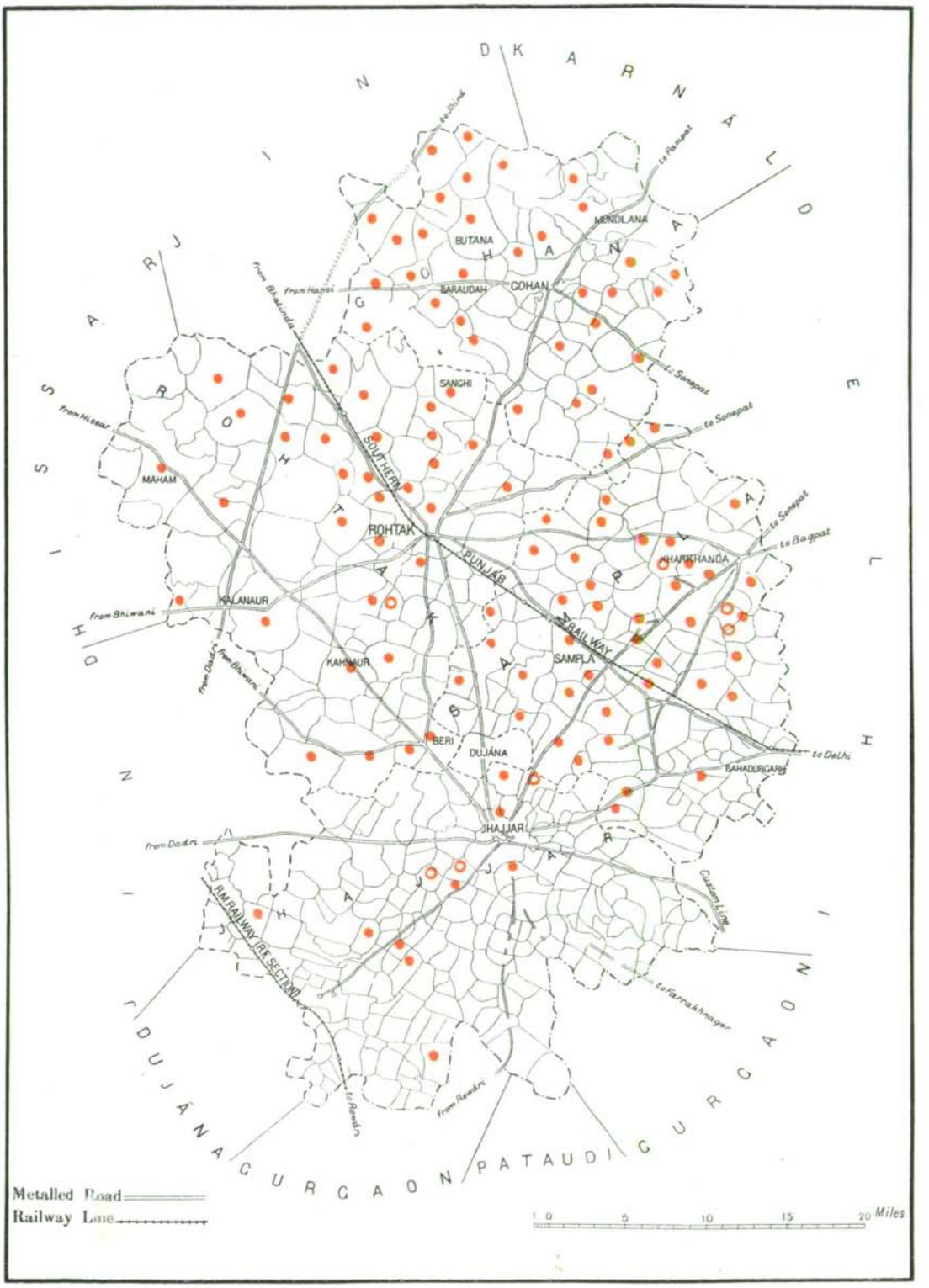


ROHTAK

May, 1907

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XLVI

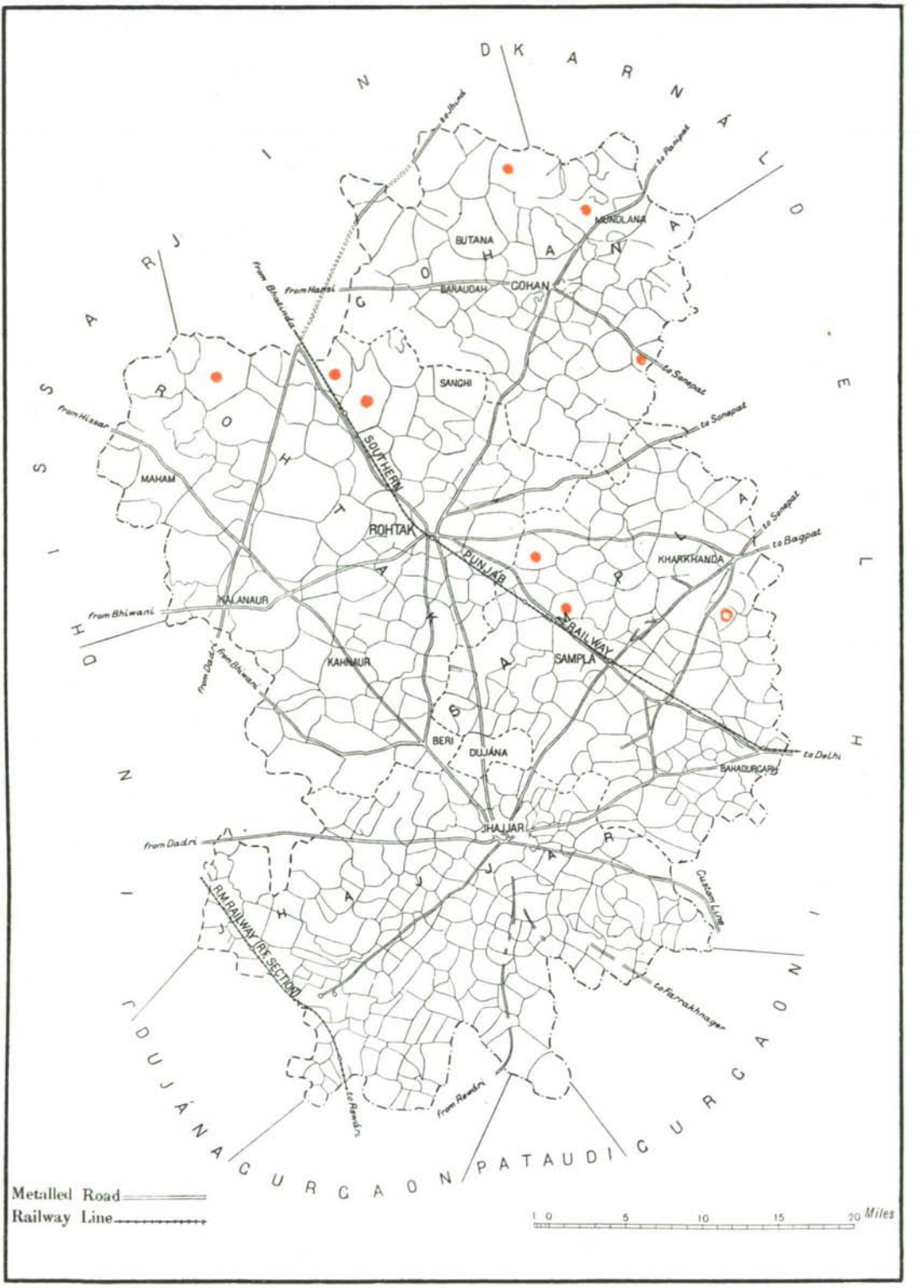


ROHTAK

June, 1907

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XLVII

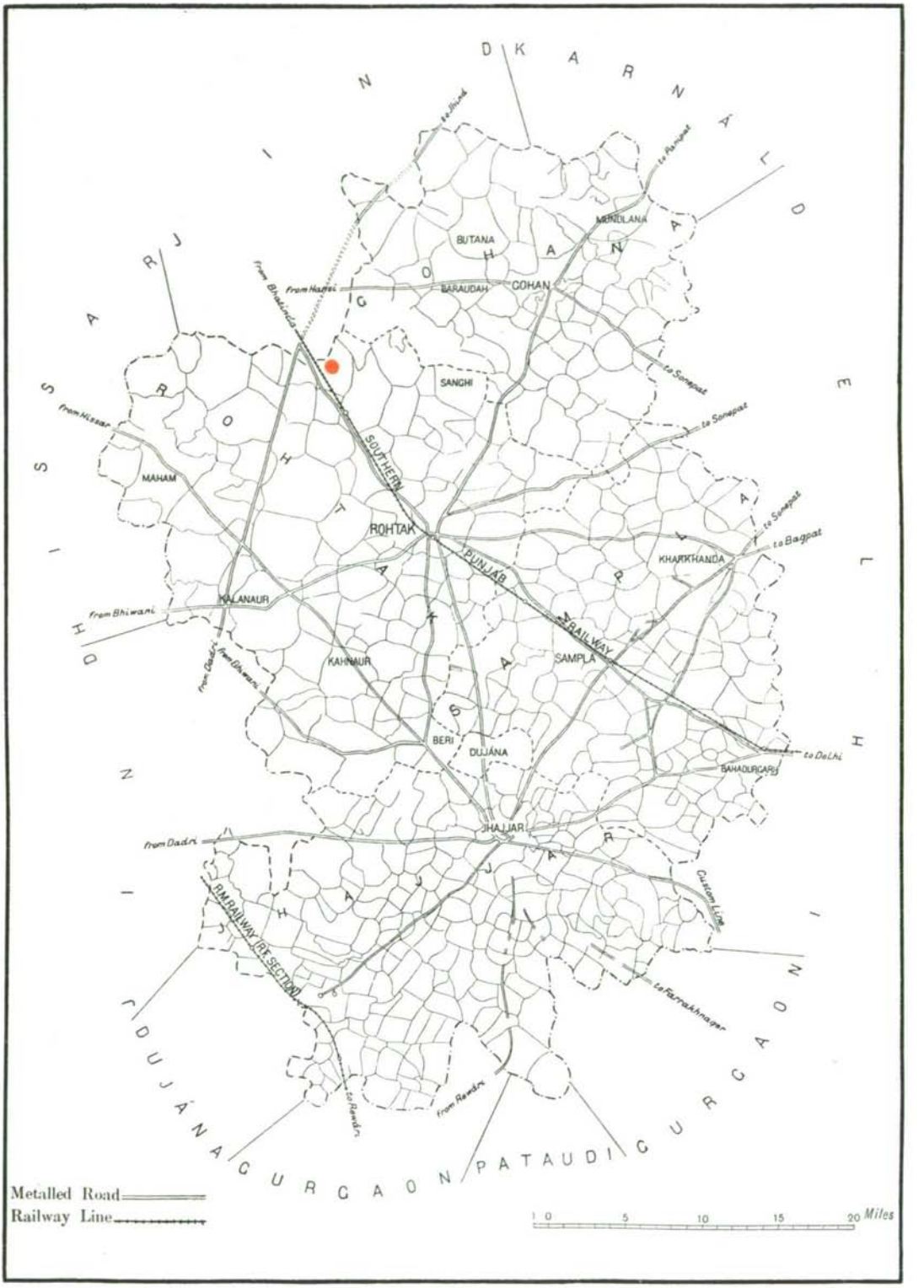


ROHTAK

July, 1907

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

MAP XLVIII



ROHTAK

August, 1907.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

The bridge over between this epidemic and that of 1903—04 is therefore clear and easily traceable. The patterns of the maps, taking into consideration the facts that the epidemic was a severe one and that it had its origin probably from several centres left over from the previous epidemic, do not differ from those of the first outbreaks. They even suggest a spread out from the centres which showed infection early in the epidemic.

(*d*) *Epidemic of* 1905—06. At the end of the epidemic of 1904—05, namely, in May and June 1905, infected villages were plentiful and were scattered over practically the whole district. It is not surprising, therefore, to find the present outbreak springing up in places widely separated from each other and also in villages which had not been infected in 1904—05. This epidemic was a small one, only 69 villages being infected. Taking into account that the infection was probably carried over from the epidemic of 1904—05 in several centres the patterns of the maps in no way differ from those of the first two epidemics.

(*e*) *Epidemic of* 1906—07. One death in each of the months of July and August 1906 was reported from the town of Kandla in the south-west corner of the district. This town had returned many deaths as late as May 1906. The epidemic proper, however, began in several centres at a distance from one another (vide October and November maps). The patterns of the maps suggest, as in the first epidemics, a spread out in the immediate neighbourhood of these centres and at the same time a spread to villages at a distance. The important thing to note is that the patterns are in no way different from those of the maps of the early epidemics, in which, as we have remarked, importation may be considered to have been the cause of the origin of the outbreaks in the villages.

C. *Amritsar District.*

(*a*) *Epidemic of* 1901—02. This epidemic, which was a small one, began in Amritsar town in February 1902.

The patterns of the map do not suggest at the beginning a regular centrifugal spread from Amritsar town. During April and May there was, however, a marked increase around Amritsar and also around some of the villages which were infected in March.

It is worthy of note that the northern tehsil of Ajnala remained practically free during the whole of this epidemic.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

(*b*) *Epidemic of* 1902—03. Amritsar City was the only place which reported plague deaths throughout the off season. The patterns of the maps suggest a spread out from Amritsar itself and from the places which first reported deaths in October 1902.

Infected villages were at first confined to the centre of the district and only later on in the epidemic did the outlying north-west and south-east portions become infected. As importation must have been the all-important factor in the spread of this epidemic the patterns of the maps should be carefully studied. 32 villages were still reporting deaths as late as July 1903.

(*c*) *Epidemic of* 1903—04. The place in which the infection remained over from the epidemic of 1902—03 to that of 1903—04 cannot be clearly demonstrated. Plague deaths were reported in Amritsar City till the end of August 1903 and appeared again in November just to the north of this City. There were two months during which no plague deaths were reported.

The patterns of the maps suggest a spread out from centres established by January 1904. They resemble those of the previous epidemic.

(*d*) *Epidemic of* 1904—05. In August 1904 a village in the north of Amritsar tehsil returned two deaths. It had not been infected during the epidemic of 1903—04, the last death having occurred 13 months previously. In September four more villages returned deaths. Three of these villages had never been infected before while the fourth had enjoyed a free interval of 15 months. It seems likely that into every one of these villages the infection was imported either from one of the others or from places infected at the end of the previous epidemic.

The patterns of the maps in no way differ from those of the previous epidemics. They suggest a spread out from villages which became infected early in the epidemic, namely, by October 1904.

(*e*) *Epidemic of* 1905—06. Amritsar town had no interval of freedom between the epidemic of 1904—05 and that of 1905—06. It was the only place which reported deaths during the months of August, September and October 1905. The patterns of the subsequent maps strongly suggest a spread out from three centres, namely, Amritsar town and centres on the north-east and east of Amritsar tehsil.

(*f*) *Epidemic of* 1906—07. Amritsar City continued to report deaths up till 25 August, 1906, bridging over a considerable portion of the off season. It was the only place which returned deaths in August.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

After this date no more deaths occurred in Amritsar town until January 1907.

The epidemic proper began in two centres, one in the north-east of the district in Ajnala tehsil and the other in the east corner. It was well advanced before Amritsar City began to return deaths. The patterns of the maps suggest a spread out from the places infected in the early months of the epidemic and in no way differ from those of previous epidemics.

D. *Summary.*

In the three districts of Rohtak, Mozuffarnagar and Amritsar the methods of spread from village to village or from four to six consecutive epidemics, beginning with the first one, have been traced on monthly maps.

The patterns of the maps of the later epidemics are of the same type as those of the first two epidemics, both of which may be presumed to have owed their spread to importation and not to recrudescence. They, as a rule, suggest a gradual spreading out from centres or foci which become established early in the epidemic. These centres of origin may not be the same in different years. In Amritsar district in some of the epidemics Amritsar City seemed to be the centre from which the infection spread, while in others it was not infected till late on in the outbreak.

III. Previous plague history of the villages infected in each epidemic.

We propose now to analyse in each district the previous plague history of the villages infected in each epidemic with the object of obtaining data regarding the relative proportion of those which had never been infected, of those which had been infected the epidemic previous, and of those which had escaped for either one or more epidemics.

The analysis of the data available is contained in Tables VIII—X. These tables require little or no explanation and all lead to the same conclusions.

In the case of the first two epidemics, as 85 to 100 p.c. of the villages infected had never before suffered from plague, importation must have been the chief factor in the origin of the outbreak

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

in each village. In the case of the epidemics either small or large following on severe ones, *e.g.* the third epidemic in Rohtak district, the fourth epidemic in Mozuffarnagar district and the third, fourth, and fifth, epidemics in Amritsar district, from 50 to 85 p.c. of the villages had been infected in the previous year. The present data in these instances, therefore, do not allow us to come to any definite conclusion as regards the relative importance of importation and recrudescence.

In all the other epidemics, however, that is to say, in those years in which the previous epidemic was slight or moderate in extent, the percentage of villages which had shown infection during any period less than 18 months is so small that unless it is possible for the infection to lie dormant over at least one epidemic season, that is to say for 18 months or longer, we must conclude that importation played the most important part in the spread of these outbreaks[1]. In addition to the data collated in these tables, we have to consider that importation is at least as likely to occur into villages which have been previously infected as into villages which have never been infected.

IV. Previous plague history of villages infected at the beginning of each epidemic.

We have already in passing drawn attention to the fact in that certain instances villages, which began to return plague deaths at the very beginning of an epidemic season, had been infected late in the previous epidemic with perhaps no interval at all or one of only two months free from deaths. This observation suggests that in these villages the infection survived probably as acute plague in the rat. We propose now to consider more fully for each district the data referring to this question, taking the villages first infected in each epidemic and inquiring into their previous plague history. We shall by this means obtain an idea of the proportion of villages reporting deaths early in an epidemic which probably harboured the infection from one epidemic to another as acute rat plague. These data are contained for Rohtak district in Tables XI—XV, for Mozuffarnagar district in Tables XVI—XX, and for Amritsar district in Tables XXI—XXVI. Tables XV, XX, and XXVI show for each district the data referring to villages in which

[1] It is possible that a rat epidemic might occur without a human epidemic. Owing to the intimate relation between men and rats in these villages, this is very unlikely: the conditions elsewhere are quite different.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

the infection was very probably carried over from one epidemic to another as acute rat plague.

The following remarks on these several tables will lead to their better understanding.

A. *Rohtak District.*

(*a*) *Epidemic of* 1903—04. (Table XI.) As this was the first introduction of plague into the district none of these villages had ever been infected before. It is, however, interesting to note that between November 1903 and February 1904 ten villages had returned plague deaths.

(*b*) *Epidemic of* 1904—05. (Table XII.) This was a very severe epidemic, following on one in which only a small proportion of the villages had been infected.

From August to November 1904 inclusive 15 villages returned plague deaths and of these nine had been infected during the previous epidemic. When we consider that only 57 villages in the whole district had been infected in 1903—04, this high proportion is strong evidence of the infection having been carried on in some at least of these villages. This presumption is supported from the fact that the interval during which no plague deaths were returned from some of the villages was a comparatively short one. Thus out of the nine villages three had a free interval of only two months, two of three months, two of four months and two of five and six months each.

In December six new villages reported deaths: none of these had been previously infected.

(*c*) *Epidemic of* 1905—06. (Table XIII.) This epidemic it will be remembered followed a very severe and widespread outbreak but was itself mild and limited in extent, only 30 villages returning deaths.

In October 1905 two villages reported deaths. Both of these villages had been infected in the previous epidemic and had been free from deaths for three or four months respectively.

In December and January four other villages began to return deaths. These four villages had also been infected in 1903—04 but had enjoyed a free interval of from five to seven months.

(*d*) *Epidemic of* 1906—07. (Table XIV.) In the epidemic of 1906—07 half the villages of the district were infected, a contrast to the previous one in which only 30 villages reported deaths. During August and September already four villages were returning deaths.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

Two of these villages had been infected in the previous epidemic and had enjoyed only two months in which no deaths occurred. The other two villages had not been infected since 1904—05 and in both instances there were 15 months during which no plague deaths had been reported.

During October, November and December, several more villages returned deaths. Of these only two had been infected in the epidemic of 1905—06 and the interval of apparent freedom was three and five months respectively.

Thus during the early months of this outbreak out of 11 villages which reported deaths only four had been infected in the previous epidemic, the intervals of freedom being in two instances two months, in a third three months, and five months in the fourth. In the case of the other seven villages no plague deaths had been reported for from 15 to 21 months.

B. *Mozuffarnagar District.*

(*a*) *Epidemic of* 1903—04. (Table XVI.) During September 1903 to January 1904 inclusive 16 villages began to report deaths from plague. Of these villages 13 had not been infected before, and three had suffered during the previous epidemic; one of these, however, had returned only one death in the epidemic of 1902—03.

In the case of both the other two villages there was an interval of three months in which no plague deaths were reported. It is also important to note that both these villages began to report cases very early in the epidemic, namely, in October 1903.

(*b*) *Epidemic of* 1904—05. (Table XVII.) The epidemic of 1904—05 was a severe one following on a comparatively mild one.

During the first four months (July—October) plague deaths occurred in 26 villages. In two of these villages the bridge over was complete, that is to say, there was no interval during which the villages were free from deaths between the beginning of this and the end of the last epidemic. One village was infected from April to September and the other from May to October inclusive. A third village, which returned one death in August but after this date none till October, had been badly infected as late as June. It is probable, therefore, that the infection was present as acute rat plague during this period, namely, June—October. A fourth village had an interval of two months, July and August, free from plague deaths. In the case of

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

other four villages which evidently had comparatively short intervals of freedom, three to five months, it is doubtful whether they were really infected or not in the outbreak of 1903—04, as each then returned only one or two deaths.

Of the remaining 18 villages, which began to return plague deaths early in this epidemic, 15 had never been infected before, and the other three had enjoyed a free interval of from 17 to 18 months, that is to say, had not been infected during the previous epidemic.

From this short account it is seen that only in a very few of the villages infected at the beginning of this epidemic was it reasonable to suppose that the origin of the disease was due to recrudescence from remnants left over from the previous epidemic. In these few villages, however, and especially in the two which had no free interval, it is likely that the infection persisted throughout the off season in an acute form amongst the rats, constituting a complete bridging over of one epidemic to the other.

(*c*) *Epidemic of* 1905—06. (Table XVIII.) This was a very small outbreak following on a very severe one.

We have analysed the previous plague history of 19 villages which began to report deaths at the beginning of the epidemic, that is to say, during August 05—February 06. Of these villages six had never been infected before; one had been infected in the 1903—04 epidemic and had enjoyed an interval of freedom for 19 months; the remaining 12 villages had been infected during the previous epidemic. But in the case of four of these villages there was only one or two deaths reported in the epidemic of 1904—05, and in three others there was only one death in the epidemic of 1905—06, so that we are justified in concluding that in none of these seven villages was it likely that the infection had survived from one epidemic to the other. That leaves us with five villages which were definitely infected in both epidemics. The intervals during which no deaths were reported in these villages was 2, 5, 7, 11 and 12 months respectively.

(*d*) *Epidemic of* 1906—07. (Table XIX.) This was a very severe epidemic, affecting as it did more than half the villages of the district. It will be remembered that it followed on a very mild outbreak.

We have traced the previous plague history of the 45 villages which were the first to report deaths, that is during the period from July to December 1906 inclusive.

Twelve of these villages had never been infected in any previous epidemics; two had not returned any deaths since the epidemic of

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

1903—04, having enjoyed a free interval of 29 and 30 months respectively: twenty had been last infected in the severe outbreak of 1904—05, having escaped in the epidemic of 1905—06. The interval of freedom from deaths in these villages varied from 17 to 22 months. In none of these villages therefore, is it at all likely that the infection survived from one epidemic to the other. We are now left to analyse the data in the case of the remaining 11 villages which were infected in the two consecutive epidemics of 1905—06, and 1906—07. From the table it will be seen that in the case of three of these villages there was only one death in one or other of the epidemics so that the infection was probably not indigenous. In the remaining eight villages the interval during which no deaths were reported varied from one to six months, and in all these, there is the possibility of the infection bridging over the epidemics as acute plague in the rat. Amongst these villages Kandla, a town with a population of over 11,000, has a most interesting history. It was infected badly in the epidemic of 1905—06, the last death being reported on 25th May, 1906. In June no deaths were reported, but in each of the months of July and August one death came to light. During September and October again no deaths were returned as due to plague, but in November between the 8th and 14th seven deaths were reported as plague. From this latter date until the 24th February, 1907, the epidemic appeared to be entirely in abeyance. It then started again and between 24th February and 4th July, 1907, 600 deaths took place.

Such a history as this appears to us strongly in favour of the supposition that in this town acute plague amongst the rats accompanied by a few human cases was present during the whole off season and bridged over the interval between the two epidemics.

C. *Amritsar District.*

(*a*) *Epidemic of* 1902—03. (Table XXI.) Amritsar City had no interval free from deaths between the epidemic of 1901—02 and that of 1902—03. In July 1902 there were three, in August 14 and in September 47 deaths. It is certain, therefore, that acute rat plague was present in the city throughout the off season.

Of the 45 villages which began to report deaths early in this epidemic, namely, in October and November, only seven had been previously infected. They had been free from deaths for from three to four months. It is probable, therefore, that in some of these villages also acute rat plague bridged over the two epidemics.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

(*b*) *Epidemic of* 1903—04. (Table XXII.) In Amritsar City the epidemic of 1902—03 was continued into August, the last death being reported on 26. VIII. 03. No more deaths were returned until January 1904 so that the bridge over of the two epidemics as acute rat plague cannot be completely demonstrated.

Up to the end of December 1903 only two villages returned plague deaths. One of these had reported a single death twelve months before while the other had enjoyed a free interval for six months.

During January 1904, 20 villages began to return deaths. Three of these had never been infected before, one had been last infected in the epidemic of 1901—02, while the remainder had reported deaths in the previous epidemic. The shortest interval of freedom, however, which any of these villages enjoyed was six months, while some of them had been free for as long as 10 to 11 months.

(*c*) *Epidemic of* 1904—05. (Table XXIII.) In August and September 1904 five villages began to return plague deaths. Three of them had never been infected before, while the other two had had free intervals of 13 and 15 months respectively. In not one of these villages, therefore, is it probable that the epidemics were bridged over by acute plague in the rat.

During October and November, 1904, 37 villages became infected. Of these villages eight had never been infected in any of the previous epidemics and 13 had been for 14 months or longer free from deaths. That leaves us with 16 villages which had reported plague deaths in the previous epidemic of 1903—04. Three of these villages had a free interval of three months, seven had four months, five had five months and one six months.

(*d*) *Epidemic of* 1905—06. (Table XXIV.) Amritsar City was still reporting plague deaths in August 1905; no free interval occurred between the end of the last epidemic and the beginning of that of 1905—06. From the beginning of August till the end of the year in this city 40 deaths were reported as being due to plague. There can be no doubt, therefore, that acute rat plague must have been present in Amritsar City throughout the whole of the off season of 1905.

During August, September and October 1905, no other place except Amritsar City reported deaths. During November and December 1905, three more villages were recognised as being infected. Only one of these had been infected in the previous epidemic, the last death having been reported in March 1905, *i.e.* there was a free interval of at least seven months.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

During January and February 1906, 22 villages began to report plague deaths. As will be seen from the Table everyone of these villages had been infected in some previous epidemic, 19 in the severe epidemic of 1904—05 and the other three in that of 1903—04. The shortest interval of freedom from deaths enjoyed by any of the villages infected in 1904—05 was five months and the longest 10 months.

(*e*) *Epidemic of* 1906—07. (Table XXV.) In August 1906 Amritsar City still continued to report deaths from plague. The last death occurred on 25. VIII. 06, and from that date till January 1907 the city was apparently free from the disease, that is to say, no deaths were returned.

In September two villages began to report. One of these villages had not been infected since December 1904, while the other had only been two months free from deaths.

In October three more villages were reported to be infected. One of these villages had never been infected before while the other two had been free from deaths for 15 and 40 months respectively.

During November and December 1906 38 new villages began to return plague deaths. Of these villages three had never been infected before, 23 had been infected in some previous epidemic but not in that of 1905—06, while the remaining 12 had returned deaths during the last epidemic, the interval of freedom enjoyed being from 4—6 months.

Lastly in Tables XV, XX and XXVI we have for each district collected together from the various epidemics the data referring to those villages in which, judging from the short period of freedom from plague deaths, the infection was probably carried over from one epidemic to the next one as acute rat plague. It would appear then that at the beginning of each epidemic amongst the first villages to report plague deaths are some in which deaths have occurred late in the previous epidemic and that there are instances in which there may be no interval of freedom at all. It is to be remembered that the data under analysis only refer to plague deaths not to cases which recover, and that it is more than likely that both cases and deaths occurring in small number in the off season would be concealed, the deaths being returned as due to some other cause. It is of course possible that the epizootic amongst the rats might continue without any plague cases in the human population, held in check by the unfavourable conditions to which we have drawn attention in another paper (*Journal of Hygiene*, vol. VIII. p. 266), namely, a mean temperature above 86° F. and a paucity of rat fleas. If, there-

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

fore, all human plague cases had come within our ken and especially if the rat population could have been examined as was done in Bombay it is probable that the bridging over the off season by acute plague in the rat would have been more clearly demonstrated and in more villages than we have been able to do with the data at our disposal.

Two points of interest and importance require mention before leaving this part of our subject. First, it is seen from the tables that the villages in which the epidemics are bridged over are of large size with a population considerably greater than that of the average village of the district. It is also seen that with few exceptions, *e.g.* Amritsar town, the villages in which apparently the infection survives the off season vary from year to year.

D. *Summary.*

Villages which return plague deaths early in an epidemic are in some instances those which were infected late in the previous epidemic. There may be no interval free from deaths or it may be as short as one to three months. In the great majority, however, of early infected villages the interval of freedom is very much longer, suggesting a fresh importation of the infection.

The villages in which one epidemic is bridged over from the previous one are as a rule of large size. They also, with the exception of the large towns such as Amritsar, vary from year to year.

V. Future plague history of the villages infected in the course of the milder epidemics.

In all three districts some of the epidemics were very mild, affecting only a comparatively small number of the total villages. It was a simple matter, therefore, to follow up the history of all these villages and to put into tabular form the data obtained. This has been done for two epidemics in two of the districts, namely Rohtak and Mozuffarnagar.

An analysis of these data throws light on the question of the bridging over of the epidemics. The data and their analysis are contained in the following tables:—

(1) Rohtak district—Tables XXVII--XXXII.
(2) Mozuffarnagar district—Tables XXXIII—XXXVIII.

To these tables the following remarks apply.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

A. *Rohtak District.*

(*a*) *Epidemic of* 1903—04. From Table XXVII it is seen that of the 57 villages which were infected during this epidemic six were not again infected and seven did not return any more deaths until the epidemic of 1906—07, that is to say, nearly two years afterwards. Further 13 villages reported less than three deaths during the epidemic under consideration, suggesting the probability that they were not truly infected but that the cases contracted their infection elsewhere. We are, therefore, left with 31 villages, which, infected in the epidemic of 1903—04, were again infected in 1904—05. It is possible, therefore, that in every one of these villages the second epidemic had its origin in remnants left over from the first one. When, however, we consider that more than half the villages of the district were infected in 1904—05 and that the great majority of them presumably owed the origin of infection to importation, it is justifiable to assume that a certain proportion of these 31 villages were also infected by importation. This assumption receives material support from an analysis of the data, which refer to the period during the second epidemic at which these villages first returned deaths (Table XXVIII) and which show the number of months during which they were free from plague deaths (Table XXIX).

From Table XXVIII it is seen that in only nine out of the 31 villages were plague deaths returned at all early in the epidemic of 1904—05, that is to say, before January 1905. Further, from Table XXIX it is seen that only in the case of seven of the villages was the free interval less than five months.

(*b*) *Epidemic of* 1905—06. We have analysed the future history of the villages infected during this epidemic in the same manner as was done with those of the 1903—04 epidemic. The data are set forth in Table XXX.

In all 30 villages returned plague deaths; four of these were not infected in the epidemic of 1906—07 and six had less than five deaths, and these we have taken to be imported cases, that is to say, received their infection elsewhere. We are, therefore, left with 20 villages which were definitely infected in both epidemics and in the case of all of which it might be argued that the infection in 1906—07 originated from remnants left over from 1905—06. But as happened in the epidemics

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

of 1903—04 and 1904—05, very few, namely, four, of these 20 villages returned deaths early in the second epidemic (Table XXXI) and the interval free from deaths was five months or less only in the case of four of the villages (Table XXXII).

B. *Mozuffarnagar District.*

(*a*) *Epidemic of* 1902—03. In Table XXXIII are set forth the details as regards plague infection of the 25 villages which reported plague deaths during this epidemic. From this table it is seen that 11 of the villages returned only one or at most two deaths, so that it is more than probable that these cases were imported and that there was no indigenous plague. They are, therefore, left out of account. Of the remaining 14 villages three were never again infected. The analysis of the data as regards the future plague history of the remaining 11 villages is set forth in Tables XXXIV and XXXV. Six of the villages were again infected in the next epidemic but only two of these six returned cases at all early in the course of the outbreak, having enjoyed a free interval of three months or less. The other four became infected well on in the epidemic at a time when many other villages were reporting deaths. We are left with five villages which, having escaped in the epidemic of 1903—04, were infected in some subsequent outbreak. They enjoyed free intervals of from 16 to 20 months.

(*b*) *Epidemic of* 1905—06. This was a more widespread epidemic than that of 1902—03, 69 villages in all reporting plague deaths. It was followed by a very severe outbreak, the last of which we take any cognizance.

The data concerning the infected villages are set forth on Table XXXVI. From an analysis of this table it is found that seven of the villages were not infected in the following epidemic leaving 62 which reported deaths in both epidemics. But in the case of nine of these villages there was only one death reported in one or other of the epidemics, so that we are left with 53 villages which can be said to have been definitely infected in both epidemics. Further analysis shows us that the great majority of these villages began to return deaths well on in the epidemic, when a great many other villages were already infected and that only a small proportion had a short interval of freedom or reported deaths early in the epidemic (Tables XXXVII and XXXVIII).

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

C. *Summary.*

A relatively small number of villages in the Rohtak district were infected in the epidemics of 1903—04 and 1905—06, and in the Mozuffarnagar district in the outbreaks of 1902—03 and 1905—06. Even when the majority of the villages which returned deaths in these epidemics were again infected in the following epidemic, analysis of the data shows that in the great majority of these villages the infection did not take place until late in the epidemic at a time when many other villages, not infected in the mild epidemic, were returning deaths. Importation, therefore, is at least equally likely to have been the origin of the second outbreak as recrudescence.

VI. Future plague history of villages infected at the end of each epidemic.

We have already seen that the villages infected at the beginning of an epidemic are sometimes, but comparatively rarely, those which have returned deaths at the end of the previous epidemic and that in some instances there may be no period of freedom from plague deaths, or that the free interval may be as short as from one to three months. We propose in this section to inquire into the future plague history of those villages which reported deaths at the end of the various epidemics in the different districts. We hope thus to obtain some idea of the proportion of late infected villages which are infected early in the next epidemic. The importance, also, of such an inquiry from a prophylactic point of view is evident. The crude data as regards the villages in Rohtak district are set forth in Table XXXIX, in Mozuffarnagar district in Table XL, and in Amritsar district in Table XLI. The analysis of these data is contained in Tables XLII—XLIV.

A. *Rohtak District.*

(*a*) *Villages infected at end of the epidemic of* 1903—04. In June 1904 nine villages had their last plague death, while in July the infection apparently remained only in one.

From all of these ten villages deaths were reported in the next epidemic, which it will be remembered was very severe and widespread. When, however, we come to consider the interval during which these

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

ten villages returned no deaths (Table XLII) we see that the majority of them did not again show infection till late on in the 1904—05 epidemic, which by that time was widespread and affecting many villages. Only three of the ten villages had a free interval of less than five months.

(*b*) *Villages infected at end of the epidemic of* 1904—05. This was a severe epidemic and a considerable number of villages still reported deaths towards the end, namely 36 in June and one in July.

What was the plague history of these 37 villages in the following epidemics of which that of 1905—06 was slight and that of 1906—07 was severe? Eight were not infected in either of these epidemics, 20 were infected in 1906—07 but not in 1905—06, leaving only nine which returned deaths in the latter epidemic. In two of these nine villages very few deaths occurred, six or under, which suggests that there may have been no indigenous plague in them.

When we now consider the interval of freedom from deaths which the 29 villages subsequently infected enjoyed we find (Table XLII) that the great majority of them were free for a long period, 19—23 months, and that all the nine villages which returned deaths in the epidemic of 1905—06 were free for at least five months and the majority of them for 8—9 months.

(*c*) *Villages infected at the end of the epidemic of* 1905—06. Of the villages infected during this mild epidemic only four still reported deaths in June, so that we shall include in our analysis eight others in which the last deaths occurred in May, 12 villages in all. Of these 12 villages three returned no deaths while nine became infected in the epidemic of 1906—07, which it will be remembered was severe and widespread. When we analyse (Table XLII) the data referring to the interval during which these villages returned no plague deaths it is seen that two had a free interval of 2 to 3 months, while the remaining seven villages did not report deaths till late on in the epidemic, when many other villages were already infected. They had enjoyed a free interval of from 7 to 10 months.

B. *Mozuffarnagar District.*

(*a*) *Villages infected at the end of epidemic of* 1902—03. In the epidemic of 1902—03, 11 villages still returned deaths in May or June 1903. Of these one was not again infected, while the period of freedom enjoyed by the other ten varied from 3 to 20 months. From Table

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

XLIII it will be seen that the great majority did not again report deaths until after an interval of more than eight months.

(*b*) *Villages infected at the end of epidemic of* 1903—04. In the epidemic of 1903—04, 22 villages were still returning plague deaths in June 1904. Two of these had no free interval, deaths continuing to occur right through the off season; two others had an interval of freedom of one and two months respectively; further, 10 more villages returned deaths in the epidemic of 1904—05, but did not begin until late on in the epidemic, at a time when many other villages were infected. The remaining eight villages were not infected till a subsequent epidemic, escaping altogether during the 1904—05 outbreak.

(*c*) *Villages infected at the end of epidemic of* 1904—05. In the epidemic of 1904—05, 35 villages returned plague deaths as late as June 1905. Of these villages seven were not again infected, 23 did not return deaths till the epidemic of 1906—07, while the remaining five were infected in the epidemic of 1905—06 but not until late on in the course of the outbreak.

(*d*) *Villages infected at the end of epidemic of* 1905—06. In the epidemic of 1905—06, which it will be remembered was a very mild one, only six villages reported deaths in June. All these were again infected during the severe epidemic of 1906—07, but deaths did not begin to occur till the epidemic was fairly well advanced, the interval of freedom enjoyed being from 4 to 8 months.

C. *Amritsar District.*

It is unnecessary to do anything further than draw attention to the table containing the data (XLI) and that showing the analysis (XLIV). These are of the same nature as those already described for Rohtak and Mozuffarnagar districts.

D. *Summary.*

Villages which return deaths at the end of one epidemic may or may not show infection during the next epidemic. Only in a very few instances is there no interval free from plague deaths between one epidemic and another and in a few more the interval is from 1 to 4 months. On the other hand the great majority of the villages infected at the end of an epidemic do not report deaths early in the subsequent

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

epidemic. They are either not infected at all or the free interval is from 6 to 10 months. By this time the epidemic is already widespread and many other villages are infected.

VII. The question whether plague tends to recur in villages in successive epidemics.

As this question is elsewhere fully discussed by Dr Greenwood we need not do more than refer to the tables annexed and to the general conclusions these would appear to us to support.

We would remind our readers that in our study of plague in the Punjab villages of Dhand and Kasel (*Journal of Hygiene*, vol. VII. p. 984) an attempt was made to determine whether houses which were infected in one epidemic were especially liable to be again infected in any subsequent epidemic, and that we arrived at the very definite conclusion that plague showed no tendency to recur in houses during successive epidemics. The same method was now used to ascertain if the villages in the three districts of Rohtak, Mozuffarnagar and Amritsar owed their infection to chance or not.

The data are given for Rohtak in Tables XLV to XLVII, for Mozuffarnagar in Tables XLVIII to L, and for Amritsar in Tables LI to LIII.

From a study of these tables which show a marked lack of correspondence between the actual and calculated figures it is evident that chances of infection were not altogether random, that is to say, that some villages were more liable to be infected than others.

On thinking over the problem it suggested itself to us that the population of the villages might be an important factor in determining whether a village would become infected or not. We have roughly tested the truth of this hypothesis in all three districts, first by comparing the average population of the villages infected in each of the epidemics, it being remembered that the epidemics varied greatly in severity, and secondly by comparing the average population of the villages infected in none of the epidemics, in one epidemic only, in any two, three etc. epidemics.

These data are contained in Tables LIV to LV for Rohtak district, Tables LVI to LVII for Mozuffarnagar district and Tables LVIII to LIX for Amritsar district. These tables all show the same phenomena.

First, it is seen that in the epidemics in which only a small number of villages returned deaths the average population of these villages was

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

very much greater than that of the villages infected in the years in which a large number reported deaths, that in fact, there was an inverse proportion between the number of villages attacked in an epidemic and the average population of these villages.

Secondly, it is seen that the average population of the villages which have enjoyed complete immunity is very small and that the greater the number of times the villages are infected the greater the average population. There is in fact a direct proportion between the number of epidemics in which villages are infected and the average population of the villages.

Thirdly, in the case of Rohtak there is another piece of evidence which shows that population is an important factor in determining the chances of infection of a village. In an early part of this paper we draw attention to the fact that in the Jhaggar tehsil of Rohtak district there were not only a smaller number of inhabitants but also a larger number of villages than in any of the other three tehsils, the result being that the average population of the villages in this subdivision was comparatively small, much below that of the other tehsils and of the district as a whole. This being so we should expect to find that the villages of the Jhaggar tehsil had suffered less than those of the other tehsils. And this expectation is shown to be correct both from the figures set forth in Table LX and from the maps 1 to 6.

From the table it is seen that, while 51·9 p.c. of the villages in Jhaggar tehsil were never infected with plague, in the other tehsils this percentage was between 7 and 19. Further it is seen that the percentage of villages in Jhaggar infected in two and three epidemics was very much less than in Rohtak, Gohana and Sampla.

In the maps 1 to 5 the villages infected in none of the epidemics, in only one epidemic, in any two, in any three and in all four epidemics respectively have been marked out. It is seen at once that as regards villages infected in all four epidemics there is no marked grouping, that Jhaggar is remarkably free from villages infected in any three epidemics and contains much the greatest number of villages infected in two epidemics and those never infected at all.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

SUMMARY.

By comparing the actual number of villages infected in none of the epidemics, in only one, in any two etc. epidemics with the number calculated on the assumption that all villages are equally liable to become infected, it is evident from the lack of correspondence between the actual and calculated figures that the assumption is not correct, that, in fact, some villages are more liable to become infected than others.

On further investigation it would appear that one factor at least which determines this greater liability to infection is the number of inhabitants, the larger villages being more often infected than the smaller.

TABLE I.

Showing the distribution of the population in the four Tehsils of the Rohtak District.

Tehsil	No. of villages	Population	Average population per village
Gohana	79	140,682	1781
Rohtak	109	195,423	1793
Sampla	124	160,262	1292
Jhaggar	187	124,455	665

TABLE II.

Showing a summary of the plague history of Rohtak District for each epidemic.

Epidemic of	Number of villages which returned deaths	Total mortality about
1903—04	37	2500
1904—05	285	27,000
1905—06	30	2000
1906—07	249	30,000

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE III.

Showing the number of villages infected month by month in each Tehsil of the Rohtak District.

Month	Year	Rohtak	Gohana	Sampla	Jhaggar	Total
January	1904	3	0	0	1	4
	1905	26	7	14	16	63
	1906	2	3	1	0	6
	1907	4	11	6	0	21
February	1904	9	0	1	5	15
	1905	36	9	34	22	101
	1906	3	5	1	0	9
	1907	10	25	13	1	49
March	1904	15	0	5	11	31
	1905	51	18	51	36	156
	1906	3	8	0	0	11
	1907	33	41	52	6	132
April	1904	15	1	8	13	37
	1905	65	46	68	53	232
	1906	8	11	1	2	22
	1907	52	57	68	19	196
May	1904	15	1	6	13	35
	1905	55	50	65	38	208
	1906	8	11	0	1	20
	1907	55	55	70	19	199
June	1904	7	1	2	2	12
	1905	7	22	33	7	69
	1906	0	4	0	0	4
	1907	34	19	44	13	110
July	1904	1	0	0	0	1
	1905	0	0	1	0	1
	1906	0	0	0	0	0
	1907	3	3	3	0	9
August	1904	0	0	1	1	2
	1905	0	0	0	0	0
	1906	1	0	0	0	1
	1907	1	0	0	0	1
September	1904	0	1	3	2	6
	1905	0	0	0	0	0
	1906	1	2	1	0	4
October	1904	2	1	3	3	9
	1905	0	1	1	0	2
	1906	1	4	2	0	7
November	1903	3	0	0	0	3
	1904	5	1	3	8	17
	1905	0	1	1	0	2
	1906	1	6	2	0	9
December	1903	4	0	0	0	4
	1904	7	4	5	7	23
	1905	0	2	1	0	3
	1906	1	8	2	0	11

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE IV

Showing the data referring to the five epidemics in Mozuffarnagar District.

Number and year of epidemic		Number of villages which returned deaths	Total mortality about
1st	1902—3	25	1256
2nd	1903—4	130	8777
3rd	1904—5	313	11,867
4th	1905—6	69	2962
5th	1906—7	579	34,933

TABLE V.

Showing month by month the number of villages which reported plague deaths in Mozuffarnagar District.

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
1902	1	0	0	1	0	0	0	0	0	0	5	2
1903	2	5	9	15	11	3	0	0	1	2	5	7
1904	11	30	51	91	52	22	4	7	12	19	36	64
1905	83	100	163	173	150	35	0	1	1	1	5	7
1906	7	12	29	46	33	6	1	1	1	7	16	35
1907	77	159	288	438	427	169	7	2	2	5	6	10

TABLE VI.

Showing data referring to the six epidemics in the Amritsar District.

Number and year of epidemic		Number of villages which returned deaths	Total mortality about
1st	1901—02	62	2509
2nd	1902—03	506	26,181
3rd	1903—04	445	22,437
4th	1904—05	669	29,930
5th	1905—06	276	8535
6th	1906—07	604	24,503

TABLE VII.

Showing month by month the number of villages which reported plague deaths in Amritsar District.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1902	0	2	8	23	30	24	7	1	1	4	46	82
1903	118	180	153	299	214	189	32	1	0	0	2	2
1904	24	47	116	329	410	117	14	1	4	17	37	93
1905	178	285	389	461	456	245	39	1	1	1	4	4
1906	14	22	62	158	222	75	11	1	2	5	20	39
1907	59	118	211	411	480	354	69	—	—	—	—	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE VIII. (*Rohtak District.*)

Showing analysis of data referring to previous plague history of villages infected each epidemic.

Number and year of epidemic		No. of villages infected	No. and percentage of villages never before infected	No. and percentage of villages infected in previous epidemic	No. and percentage of villages which escaped infection for one epidemic	No. and percentage of villages which escaped infection for two epidemics
1st	1903—04	57	57 (100 p.c.)	—	—	—
2nd	1904—05	285	241 (85 p.c.)	44 (15 p.c.)	—	—
3rd	1905—06	30	4 (13·3 p.c.)	26 (86·7 p.c.)	—	—
4th	1906—07	249	52 (20·9 p.c.)	26 (10·4 p.c.)	164 (65·9 p.c.)	7 (2·8 p.c.)

TABLE IX. (*Mozuffarnagar District.*)

Showing analysis of data referring to the previous plague history of villages infected each epidemic.

Number and year of epidemic		No. of villages infected	No. and percentage of villages never before infected	No. and percentage of villages infected in previous epidemic	No. and percentage of villages which escaped infection during one epidemic	No. and percentage of villages which escaped infection in two epidemics	No. and percentage of villages which escaped infection in three epidemics
1st	1902—03	25	25 (100 p.c.)	—	—	—	—
2nd	1903—04	130	121 (93 p.c.)	9 (7 p.c.)	—	—	—
3rd	1904—05	313	220 (70·3 p.c.)	82 (26·2 p.c.)	11 (3 p.c.)	—	—
4th	1905—06	69	24 (34·8 p.c.)	41 (59·4 p.c.)	4 (5·8 p.c.)	—	—
5th	1906—07	579	249 (43 p.c.)	62 (10·7 p.c.)	227 (39·4 p.c.)	39 (6·6 p.c.)	2 (0·3 p.c.)

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE X. (*Amritsar District.*)

Showing analysis of data referring to the previous plague history of villages infected each epidemic.

Number and year of epidemic		Total no. of villages infected	No. and percentage of villages never before infected	No. and percentage of villages infected in previous epidemic	No. and percentage of villages which escaped infection in one epidemic only	No. and percentage of villages which escaped infection in two epidemics	No. and percentage of villages which escaped infection in three epidemics	No. and percentage of villages which escaped infection in four epidemics
1st	1901—02	62	62 (100 p.c.)	—	—	—	—	—
2nd	1902—03	506	462 (91·3 p.c.)	44 (8·7 p.c.)	—	—	—	—
3rd	1903—04	445	149 (33·5 p.c.)	286 (64·2 p.c.)	10 (2·3 p.c.)	—	—	—
4th	1904—05	669	166 (24·8 p.c.)	345 (51·6 p.c.)	153 (22·9 p.c.)	5 (0·7 p.c.)	—	—
5th	1905—06	276	9 (3·3 p.c.)	230 (83·3 p.c.)	26 (9·5 p.c.)	10 (3·6 p.c.)	1 (0·3 p.c.)	—
6th	1906—07	604	59 (9·8 p.c.)	201 (33·3 p.c.)	290 (48 p.c.)	31 (5·1 p.c.)	22 (3·6 p.c.)	1 (0·2 p.c.)

TABLE XI.

Data referring to villages in Rohtak District infected in the beginning of the 1903—04 *epidemic.*

No. of village	Tehsil	Population	Month when first infected	Remarks
112	Rohtak	9723	November '03	—
28	,,	7824	,,	—
32	,,	4191	,,	—
113	,,	609	January '04	Probably infected from 112 in immediate neighbourhood.
114	,,	519	,,	
194	Jhaggar	2469	,,	—
171	,,	3896	February '04	—
135	,,	3602	,,	—
62	,,	12,227	,,	—
81	Sampla	598	,,	Infected probably from Beri neighbourhood.

N.B. As this was the first epidemic none of these villages had been previously infected.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XII.

Data referring to villages in Rohtak District infected at the beginning of the 1904—05 *epidemic.*

No. of village	Tehsil	Population	Month when first infected in 1904-05 epidemic	Month when last death was reported in 1903-04 epidemic	No. of months free from deaths	Remarks
81	Sampla	598	August	May	2	Infected Feb.—May 04.
164	Jhaggar	531	,,	Nil	—	—
62	,,	12,227	September	May	3	Infected Feb.—May 04.
93	Sampla	5316	,,	June	2	Infected Mar.—June 04.
74	,,	5060	,,	June	2	Infected Mar.—June 04.
26	Gohana	2343	,,	Nil	—	—
85	Rohtak	20,024	October	May	4	Had a few deaths Feb. —May 04.
112	,,	9723	,,	June	3	Infected Feb.—May 04.
32	Jhaggar	1104	,,	May	4	Had a few deaths Ap.— May 04.
76	Sampla	286	,,	Nil	—	—
53	Rohtak	5024	November	May	5	Few deaths Ap.—May 04.
40	,,	1931	,,	Nil	—	—
90	,,	1173	,,	Nil	—	—
135	Jhaggar	3602	,,	April	6	Few deaths Feb. —Ap. 04.
102	,,	885	,,	Nil	—	—
94	Rohtak	1735	December	Nil	—	—
74	Jhaggar	1823	,,	Nil	—	—
20	Sampla	3309	,,	Nil	—	—
16	Gohana	7509	,,	Nil	—	—
56	,,	485	,,	Nil	—	—
59 A	,,	383	,,	Nil	—	—

TABLE XIII.

Data referring to villages in Rohtak District infected at the beginning of the 1905—06 *epidemic.*

No. village	Tehsil	Population	Month when first infected in 1905-06 epidemic	Month when last death was reported	No. of months free from deaths	Remarks
31	Gohana	4241	October	June 05	3	—
104	Sampla	266	,,	May 05	4	Only village infected in Sampla Tehsil in this epidemic.
3	Gohana	2443	December	June 05	5	—
13	,,	3185	January	June 05	6	—
21	Rohtak	2783	,,	May 05	7	—
112	,,	9723	,,	May 05	7	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XIV.

Data referring to villages in Rohtak District infected at beginning of the 1906—07 *epidemic.*

No. of village	Tehsil	Population	Month when first infected in 1906-07 epidemic	Month when last death was reported	No. of months free from deaths
11	Rohtak	5126	August	May 06	2
17	Gohana	5836	September	May 05	15
31	,,	4241	,,	June 06	2
12	Sampla	3765	,,	May 05	15
32	,,	2606	October	June 05	15
39	Gohana	5657	,,	June 06	3
58	,,	1660	,,	May 05	16
47	,,	2470	November	May 06	5
26	,,	2343	,,	Jan. 05	21
27	,,	3247	December	May 05	18
57	,,	1178	,,	May 05	18

TABLE XV.

Data referring to villages in Rohtak District in which the infection was probably carried over each year from one epidemic to the other as acute rat plague.

No. of village	Tehsil	Population	Months when first and last deaths took place in 1st epidemic	No. of deaths in 1st epidemic	Month when 1st death took place in 2nd epidemic	No. of months free from deaths
Between 1st and 2nd epidemics :						
81	Sampla	698	Feb.—May 04	61	August 04	2
93	,,	5316	Mar.—June 04	100	Sept. 04	2
74	,,	5060	Ap.—June 04	75	Sept. 04	2
62	Jhaggar	12,227	Feb.—May 04	42	Sept. 04	3
112	Rohtak	9723	Feb.—June 04	519	Oct. 04	3
Between 2nd and 3rd epidemics :						
31	Gohana	4241	May—June 05	31	Oct. 05	3
104	Sampla	266	Ap.—May 05	5	Oct. 05	4
Between 3rd and 4th epidemics :						
11	Rohtak	5126	Ap.—May 06	13	Aug. 06	2
31	Gohana	4241	May—June 06	55	Sept. 06	2
39	,,	5657	Ap.—June 06	32	Oct. 06	3

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XVI.

Data referring to villages in Mozuffarnagar District infected at the beginning of the epidemic of 1903—04.

Name	Population	Thana	Month when infection began	Month when last previous death occurred	No. of months free	Remarks
Kadargarh	618	Thana Bawan	Sept. 03	Nil	—	—
Mozuffarnagar	23,444	Mozuffarnagar	Oct. 03	June 03	3	—
Khatauli	8695	Khatauli	,,	,,	3	—
Sandholi	418	,,	Nov. 03	Nil	—	—
Mukimpur	2668	Meranpur	,,	Nil	—	—
Kailaoda Kalan	2140	Khatauli	,,	May 03	5	Only 1 case in ep. of 1902–03.
Naola	3752	,,	Dec. 03	Nil	—	—
Titawa	1192	,,	,,	Nil	—	—
Jauli	2579	Bhopa	,,	Nil	—	—
Khandla	11,563	Khandla	,,	Nil	—	—
Sarai	2752	Khatauli	Jan. 04	Nil	—	—
Barsu	1457	,,	,,	Nil	—	—
Pipalhera	1184	,,	,,	Nil	—	—
Nagli	542	,,	,,	Nil	—	—
Jansath	6507	Jansath	,,	Nil	—	—
Kukra	3205	Shahpur	,,	Nil	—	—

TABLE XVII.

Data referring to villages in Mozuffarnagar District infected at the beginning of the epidemic of 1904—05.

Name	Population	Thana	Month when infection began	Month when last previous death occurred	No. of months free	Remarks
Tijalhera	2385	Purkazi	July 04	June 04	0	—
Belra	1809	Bhopa	,,	,,	0	—
Gianna Mazra	790	Charthawal	,,	Nil	—	—
Arnaki	167	,,	,,	Nil	—	—
Meranpur	7209	Meranpur	Aug. 04	June 04	1	Only 1 death in Aug. 04.
Jandheri	1019	Jansath	,,	Nil	—	—
Goela	3098	Shahpur	,,	Nil	—	—
Harsauli	3069	Titawi	,,	Nil	—	—
Rani	1753	Charthawal	,,	Nil	—	—
Pur	6384	Purkazi	Sept. 04	May 04	3	Only 2 deaths in Sept. 04.
Tisa	3384	Bhopa	,,	June 04	2	—
Chaurawala	1543	,,	,,	Nil	—	—
Kethora	2668	Meranpur	,,	April 04	4	Only 2 deaths in April 04.
Chandam	471	Jansath	,,	Nil	—	—
Kalyanpur	830	Shahpur	,,	Nil	—	—
Bitanda	2663	Budhana	,,	April 03	17	—
Bhukarheri	6316	Bhopa	Oct. 04	Nil	—	—
Murahlpur	3	,,	,,	Nil	—	—
Barkara	1220	,,	,,	Nil	—	—
Karehra	1220	,,	,,	Nil	—	—
Kanarhen	527	Charthawal	,,	Nil	—	—
Rasulpur Khurd	418	Meranpur	,,	April 04	5	Only 1 death in April 04.
Antwara	1721	Jansath	,,	,,	5	Ditto.
Basayach	889	,,	,,	Nil	—	—
Karthal	1823	Budhana	,,	May 03	17	—
Mandoli	313	,,	,,	April 03	18	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XVIII.

Data referring to villages in Mozuffarnagar District infected at the beginning of the epidemic of 1905—06.

Name	Population	Thana	Month when infection began	Month when last previous death occurred	No. of months free	Remarks
Jansath	6507	Jansath	Aug. 05	May 05	2	—
Loi	7095	Kandhla	Oct. 05	Nil	—	—
Kutesra	3565	Charthawal	Nov. 05	Mar. 05	7	—
Kamhera	1197	Jansath	,,	,,	—	Only 1 death in 1904—05.
Balla Mazra	771	Chausana	,,	April 05	—	Only 2 deaths in 1904—05.
Bhuma	1893	Meranpur	,,	May 05	—	Only 1 death in 1905—06.
Dathera	1245	Chausana	Dec. 05	April 05	—	Ditto.
Shamli	7478	Shamli	,,	June 05	5	—
Karnali	1078	,,	,,	Nil	—	—
Mustgarh	359	Thanabhawan	Jan. 06	Nil	—	—
Harsauli	3069	Titawi	,,	May 05	—	Only 1 death in 1904—05.
Balwa	2503	Shamli	Feb. 06	Mar. 05	—	Ditto.
Lank	3863	,,	,,	June 04	19	—
Mandwara	607	Budhana	,,	Nil	—	—
Nirmani	877	Titawi	,,	Nil	—	—
Ghesu Khera	571	Charthawal	,,	Jan. 05	—	Only 1 death in
Pura	805	Khatauli	,,	Nil	—	1905—06.
Gadla	1767	Bhopa	,,	Jan. 05	12	—
Bhu Karheri	6316	,,	,,	Feb. 05	11	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XIX.

Data referring to villages in Mozuffarnagar District infected at the beginning of the epidemic of 1906—07.

Name	Population	Thana	Month when infection began	Month when last previous death occurred	No. of months free	Remarks
Kandla	11,563	Kandla	July 06	May 06	1	1 death in July. 1 death in Aug. 7 deaths in Nov.
Kasauli	1323	Charthawal	Sept. 06	,,	—	Only 1 death in 1906—07.
Rasulpur	851	Shahpur	Oct. 06	April 04	29	—
Nizampur	299	Khatauli	,,	Nil	29	—
Meranpur	7209	Meranpur	,,	April 04	17	—
Wazirabad	669	Bhopa	,,	Feb. 05	19	—
Chachrauli	871	,,	,,	Nov. 04	22	—
Yusafpur	824	,,	,,	Nil	22	—
Chaurawala	1543	,,	,,	May 06	4	—
Alayarpur	552	Shahpur	Nov. 06	Nil	4	—
Baghrli	4935	Titawi	,,	May 05	17	—
M. Nagar	23,444	M. Nagar	,,	June 06	4	—
Chandpur	1109	,,	,,	May 06	5	—
Bilaspur	1390	,,	,,	Feb. 05	20	—
Khojahera	999	Jansath	,,	May 05	17	—
Sikri	3026	Bhopa	,,	May 06	5	—
Jauli	2579	,,	,,	June 06	4	—
Pur	6384	Purkazi	,,	May 05	17	—
Garhi-Hasanpur	1461	Chausana	,,	May 05	17	—
Toda	800	,,	Dec. 06	Nil	—	—
Bhikki-Mazra	487	Shamli	,,	May 05	17	—
Amernagar	1939	Titawi	,,	Mar. 05	20	—
Kanami	2508	,,	,,	May 05	18	—
Makhyali	1851	M. Nagar	,,	Feb. 05	21	—
Dhudhera	872	,,	,,	Nil	—	—
Khatauli	3695	Khatauli	,,	Mar. 05	20	—
Talra	1214	Jansath	,,	May 06	—	Only 1 death, May 06.
Palri	520	,,	,,	May 05	18	—
Mahalki	1365	,,	,,	April 05	19	—
Antnara	1721	,,	,,	,,	19	—
Jansath	6507	,,	,,	June 06	5	—
Chitaura	1762	,,	,,	May 06	6	—
Karandah	1349	,,	,,	Nil	—	—
Kethora	2668	Meranpur	,,	Mar. 05	18	—
Gadhi-Rasulpur	418	,,	,,	Nil	—	—
Mukimpur	2668	,,	,,	Feb. 05	21	—
Kakranli	3985	Bhopa	,,	,,	21	—
Teora	2699	,,	,,	June 06	—	Only 1 death, May 05—06.
Berah-Sadat	1522	,,	,,	Feb. 05	21	—
Bhoapur	676	,,	,,	Nil	—	—
Malpura	635	,,	,,	Nil	—	—
Khudda	2441	Purkazi	,,	May 04	30	—
Harainti	519	,,	,,	Nil	—	—
Lakhnanti	300	,,	,,	Nil	—	—
Aterna	1304	Budhana	,,	Nil	—	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XX.

Data referring to villages in Mozuffarnagar District in which the infection was probably carried over from one epidemic to another as acute rat plague.

Name	Thana	Population	Months when first and last deaths took place in 1st epidemic	No. of deaths in 1st epidemic	Month when first death took place in 2nd epidemic	No. of months free from deaths
Mozuffarnagar	M. Nagar	23,444	Feb.—June 03	25	Oct. 03	3
Khatauli	Khatauli	8695	Mar.—June 03	4	Oct. 03	3
Tijalhera	Purkazi	2385	April—July 04	120	Aug. 04	0
Belra	Bhopa	1809	May—July 04	68	Aug. 04	0
Meranpur	Meranpur	7209	Mar.—June 04	151	Aug. 04	1
Pur	Purkazi	6384	Mar.—May 04	279	Sept. 04	3
Tisa	Bhopa	3384	April—June 04	29	Sept. 04	2
Jansath	Jansath	6507	Jan.—May 05	146	Aug. 05	2
Kandla	Kandla	11,563	April—May 06	52	July 06	1

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXI.

Data referring to villages in Amritsar District infected at beginning of 1902—03 *epidemic.*

No.	Tehsil	Population	Month when became infected	Month of last previous death	No. of months free	Remarks
113	Amritsar	162,429	Aug. 02	July 02	0	Amritsar City
24	,,	1525	Oct. 02	June 02	3	3 deaths, May —June 02.
17	,,	6490	,,	Nil	—	
144	Ajnala	429	,,	Nil	—	—
110	Amritsar	990	Nov. 02	Nil	—	—
38	,,	317	,,	Nil	—	—
202	,,	230	,,	Nil	—	—
175	,,	238	,,	Nil	—	—
42	,,	407	,,	Nil	—	—
222	,,	868	,,	Nil	—	—
60	,,	946	,,	Nil	—	—
138	,,	307	,,	Nil	—	—
16	,,	958	,,	Nil	—	—
143	,,	1470		July 02	3	—
63	,,	1700	,,	,,	3	1 death in Nov. 02.
109	,,	1323	,,	Nil	—	
39	,,	1090	,,	Nil	—	1 death in July 02.
171	,,	1144	,,	June 02	4	—
201	,,	1966	,,	Nil	—	—
239	,,	1076	,,	Nil	—	—
67	,,	1019	,,	Nil	—	—
176	,,	1863	,,	Nil	—	—
64	,,	1117	,,	Nil	—	—
65	,,	1826	,,	Nil	—	—
169	,,	1959	,,	Nil	—	—
27	,,	5029	,,	Nil	—	—
64	,,	1130	,,	Nil	—	—
46	Tarn-Tarn	1114	,,	June 02	4	—
28	,,	1628	,,	Nil	—	—
42	,,	2208	,,	June 02	4	—
49	,,	2440	,,	July 02	3	—
80	,,	1742	,,	Nil	—	—
41	,,	4161	,,	Nil	—	—
165	,,	331	,,	Nil	—	—
121	,,	1067	,,	Nil	—	—
150	,,	3206	,,	Nil	—	—
100	,,	930	,,	Nil	—	—
33	,,	518	,,	Nil	—	—
120	,,	4428	,,	Nil	—	—
146	Ajnala	564	,,	Nil	—	—
270	,,	2439	,,	Nil	—	—
145	,,	1514	,,	Nil	—	—
162	,,	1166	,,	Nil	—	—
180	,,	405	,,	Nil	—	—
161	,,	954	,,	Nil	—	—
162 A	,,	349	,,	Nil	—	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXII.

Data referring to villages in Amritsar District infected at the beginning of 1903—04 *epidemic.*

No.	Tehsil	Population	Month when became infected	Month of last previous death	No. of months free	Remarks
713	Amritsar	162,429	Aug. 03	July 03	0	—
63	,,	1700	Nov. 03	Nov. 02	11	1 case in Nov. 02.
258	Ajnala	2179	,,	April 03	6	—
57	Amritsar	1500	Jan. 04	June 03	6	—
143	,,	1470	,,	Jan. 03	11	—
83	,,	878	,,	June 03	6	—
40	,,	1868	,,	May 03	7	—
196	,,	1600	,,	June 02	18	—
262	,,	3029	,,	May 03	7	—
136	,,	258	,,	Nil	—	—
146	,,	5817	,,	June 03	6	—
236	,,	916	,,	April 03	8	—
268	,,	1158	,,	May 03	7	—
216	,,	2494	,,	June 03	6	—
89	,,	3709	,,	April 03	8	—
176	,,	1863	,,	Feb. 03	10	—
138	Tarn-Tarn	801	,,	May 03	7	—
264	,,	4343	,,	June 03	6	—
323	,,	1846	,,	Nil	—	—
41	,,	4161	,,	Feb. 03	10	—
67	,,	1597	,,	Mar. 03	9	—
120	,,	4428	,,	April 03	8	—
311	,,	3654	,,	Nil	—	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXIII.

Data referring to villages in Amritsar District infected at the beginning of 1904—05 *epidemic.*

No.	Tehsil	Population	Month when became infected	Month of last previous death	No. of months free	Remarks
1	Amritsar	263	Aug. 04	June 03	13	2 deaths only in
167	,,	715	Sept. 04	Nil	—	Aug., 1 death in
25	,,	637	,,	Nil	—	Sept.
261	,,	1033	,,	May 03	15	—
189	Tarn-Tarn	730	,,	Nil	—	—
57	Amritsar	1500	Oct. 04	May 04	4	—
306	,,	524	,,	Nil	—	—
292	,,	1776	,,	Nil	—	—
103	,,	867	,,	April 04	5	—
102	,,	209	,,	Nil	—	—
317	,,	1062	,,	June 04	3	—
308	,,	843	,,	Feb. 03	19	—
291	,,	430	,,	Nil	—	—
142	Tarn-Tarn	2107	,,	June 04	3	—
241	,,	792	,,	June 03	15	—
243	,,	3538	,,	May 03	16	—
31	,,	238	,,	May 04	4	—
159	,,	1513	,,	June 04	3	—
210	Ajnala	1891	,,	July 03	14	—
146	,,	1514	,,	May 04	4	—
100	Amritsar	1517	Nov. 04	June 03	16	—
163	,,	1411	,,	June 03	16	—
327	,,	1143	,,	Nil	—	—
267	,,	1011	,,	June 03	16	—
116	,,	639	,,	Nil	—	—
78	,,	1470	,,	May 04	5	—
77	,,	611	,,	June 03	16	—
288	,,	1073	,,	June 04	4	—
276	,,	1772	,,	June 04	4	—
343	,,	1062	,,	June 04	4	—
32	,,	502	,,	Nil	—	—
176	,,	1863	,,	April 04	6	—
51	Tarn-Tarn	326	,,	June 03	16	—
190	,,	220	,,	May 03	17	—
269	,,	3400	,,	May 04	5	—
230	,,	247	,,	June 03	16	—
66	,,	1090	,,	June 04	4	—
226	,,	3291	,,	June 03	16	—
67	,,	1597	,,	May 04	5	—
215	,,	2737	,,	June 03	16	—
85	,,	1201	,,	May 04	5	2 deaths in May
273	,,	581	,,	Nil	—	04.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXIV.

Data referring to villages in Amritsar District infected at the beginning of 1905—06 *epidemic.*

No.	Tehsil	Population	Month when became infected	Month of last previous death	No. of months free	Remarks
113	Amritsar	162,429	Aug. 05	July 05	0	—
700	,,	1517	Nov. 05	Mar. 05	7	—
60	,,	946	,,	May 04	17	—
59	,,	154	,,	May 04	17	1 death in May 04.
175	,,	238	Jan. 06	April 05	8	—
71	,,	1794	,,	April 05	8	—
249	,,	1306	,,	May 05	7	—
159	,,	533	,,	Mar. 05	9	—
72	,,	1520	,,	April 05	8	—
86	,,	1829	,,	June 05	6	—
78	,,	1470	,,	Mar. 05	9	—
57	Tarn-Tarn	1177	,,	Feb. 05	10	—
66	,,	1090	,,	July 05	5	—
69	,,	469	,,	May 04	19	—
113	,,	2463	,,	May 05	7	1 death in Jan. 06.
59	,,	1433	,,	July 05	5	—
96	Amritsar	1602	Feb. 06	June 05	6	—
275	,,	2431	,,	Mar. 05	9	—
201	,,	432	,,	May 05	7	—
261	,,	1033	,,	Mar. 05	9	—
111	,,	1364	,,	June 05	6	—
288	,,	1520	,,	April 05	8	—
37	,,	2830	,,	June 04	18	—
42	Tarn-Tarn	2208	,,	June 04	18	—
287	Ajnala	763	,,	June 05	6	—
109	,,	692	,,	April 05	8	1 death in Feb. 06.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXV.

Data referring to villages in Amritsar District infected at the beginning of 1906—07 *epidemic.*

No.	Tehsil	Population	Month when became infected	Month of last previous death	No. of months free	Remarks
113	Amritsar	162,429	Aug. 06	July 06	0	Last death
291	,,	430	Sept. 06	Dec. 04	20	25. 8. 06, then
235	Tarn-Tarn	979	,,	June 06	2	in Jan. 07.
123	,,	2303	Oct. 06	June 05	15	—
183	Ajnala	843	,,	May 03	40	—
165	,,	323	,,	Nil	—	—
43	Amritsar	1479	Nov. 06	May 05	17	—
57	,,	1500	Nov. 04	Dec. 04	22	—
322	,,	1335	,,	Feb. 05	20	—
69	,,	993	,,	June 05	16	—
302	,,	734	,,	May 06	5	—
38	,,	511	,,	April 04	30	—
78	,,	1470	,,	April 06	6	—
72	Tarn-Tarn	1298	,,	April 05	18	—
147	Ajnala	773	,,	Nil	—	—
5	,,	1209	,,	May 04	29	1 death in 1906
181	,,	943	,,	May 05	17	—07.
213	,,	775	,,	May 03	41	—
113	,,	957	,,	May 05	17	—
245	,,	3198	,,	June 05	16	—
183 A	,,	843	,,	May 03	41	—
124	Amritsar	436	Dec. 06	April 05	19	—
325	,,	2090	,,	June 06	5	—
312	,,	2110	,,	May 06	6	1 death in 1906
284	,,	692	,,	April 05	19	—07.
96	,,	1602	,,	May 06	6	—
279	,,	1664	,,	July 06	4	—
143	,,	1470	,,	May 05	18	—
240	,,	234	,,	May 05	18	—
229	,,	1779	,,	June 06	5	—
318	,,	897	,,	May 05	18	2 deaths in Dec.
123	,,	321	,,	Nil	—	no more till
101	,,	1346	,,	June 06	5	April.
41	,,	319	,,	May 06	6	—
341	,,	1119	,,	June 06	5	—
26	,,	5029	,,	May 05	18	—
206	Tarn-Tarn	951	,,	Feb. 05	21	—
206 A	,,	1467	,,	June 06	5	—
21	Ajnala	374	,,	May 05	18	2 deaths only
162	,,	1166	,,	May 05	18	in 1906—07.
161	,,	383	,,	Nil	—	—
273	,,	4511	,,	June 06	5	—
245 A	,,	3198	,,	June 04	29	—
181 A	,,	298	,,	May 05	18	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXVI.

Data referring to villages in Amritsar District in which the infection was probably carried over from one epidemic to another as acute rat plague.

No.	Tehsil	Population	Months when first and last deaths took place in 1st epidemic	No. of deaths in 1st epidemic	Month when first death took place in 2nd epidemic	No. of months free from deaths
113	Amritsar	162,429	Feb.—July 02	82	Aug. 02	0
24	,,	1525	May—June 02	3	Oct. 02	3
143	,,	1470	April—July 02	35	Nov. 02	3
63	,,	1700	July 02	2	Nov. 02	3
49	Tarn-Tarn	2440	May—July 02	14	Dec. 02	3
113	Amritsar	162,429	Aug. 02, July 03	460	Aug. 03	0
317	,,	1062	May—June 04	3	Oct. 04	3
142	Tarn-Tarn	2107	April—June 04	25	Oct. 04	3
159	,,	1513	April—June 04	13	Oct. 04	3
113	Amritsar	162,429	Jan.—July 05	1073	Aug. 05	0
113	,,	162,429	Aug. 05, July 06	1903	Aug. 06	0
235	Tarn-Tarn	979	May—June 06	15	Sept. 06	2

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXVII.

Data referring to villages in Rohtak District infected in the epidemic of 1903—04.

No. of village	Tehsil	Population	Details of infection of 1903—04: Months during which deaths were returned	Details of infection of 1903—04: No. of deaths	Details of next subsequent infection: Months during which deaths were returned	Details of next subsequent infection: No. of deaths	No. of months free from deaths
100	Rohtak	1032	Feb.—May	31	Nil	Nil	—
186	Jhaggar	210	May	1	Nil	Nil	—
71	,,	384	April—May	8	Nil	Nil	—
109	,,	361	Mar.—May	8	Nil	Nil	—
78	,,	767	Mar.—May	54	Nil	Nil	—
14	,,	419	May	1	Nil	Nil	—
95	Rohtak	1934	Mar.—May	121	Jan.—May 05	156	7
99	,,	1193	Mar.—June	30	April—June 05	54	9
93	,,	363	March	1	April 05	3	—
35	Sampla	2231	Mar.—May	175	Mar.—June 05	137	9
134	Jhaggar	296	June	1	Mar.—April 05	18	—
140	,,	231	May	2	Jan. 05	4	—
10	,,	637	Mar.—May	9	April—May 05	20	10
153	,,	572	Mar.—April	20	April—May 05	16	11
75	,,	645	May—June	23	April—May 05	31	9
171	,,	3896	Feb.—May	108	Mar.—May 05	101	9
135	,,	3602	Feb.—April	13	Nov. 04—Mar. 05	160	6
194	,,	2469	Jan.—Feb.	8	April—June 05	84	13
93	,,	956	March	1	April—June 05	36	—
155	,,	327	Mar.—May	23	April 05	53	10
81	Sampla	598	Feb.—May	61	Aug.—Sept. 04	12	2
113	Rohtak	609	Jan.—May	26	April—May 05	38	10
107	,,	4279	Feb.—June	204	April—May 05	19	9
108	,,	4076	Mar.—July	296	Jan.—May 05	21	5
96	,,	663	April	16	Mar.—May 05	60	10
15	,,	511	Feb.—April	62	April—May 05	50	11
65	,,	1285	Mar.—May	25	Mar.—April 05	39	9
32	,,	4191	Nov.—May	333	Feb.—May 05	315	8
33	,,	759	Feb.—May	24	April—June 05	18	10
31	,,	2463	Mar.—June	180	Mar.—June 05	162	8
53	,,	5024	April—May	15	Nov. 04—Mar. 05	98	5
28	,,	7824	Nov.—Dec.	6	Jan.—May 05	441	12
49	,,	4074	Jan.	1	Jan.—May 05	208	—
68	,,	1865	May	1	Mar.—May 05	139	—
31	Sampla	2164	April	1	Jan.—June 05	199	—
74	,,	5060	April—June	75	Sept. 04—June 05	334	2
12	,,	3765	March	1	Jan.—Mar. 05	224	—
95	,,	706	April—May	13	Feb.—April 05	29	8
68	,,	1887	April	3	Jan.—May 05	117	—
83	Gohana	4013	April	1	April—May 05	31	—
161	Jhaggar	1432	March	1	Mar.—May 05	90	—
60	,,	1031	April	3	Feb.—May 05	43	—
62	,,	12,227	Feb.—May	42	Sept.—Dec. 04	274	—
112	Rohtak	9723	Nov.—June	525	Oct. 04—May 05	208	3
85	,,	20,024	Feb.—May	12	Oct. 04—May 05	900	4
35	,,	7640	Mar.—June	262	Jan.—May 05	265	6
21	,,	3783	March	1	April—May 05	71	—
93	Sampla	5316	Mar.—June	100	Sept. 04—June 05	324	2
29	Gohana	1035	May—June	31	April—May 05	38	9
32	Jhaggar	1104	April—May	6	Oct. 04—June 05	59	4
128	,,	603	April	1	April 07	1	—
18	,,	1298	Nov.	1	Mar.—April 07	2	—
62	Sampla	1415	April	1	Feb.—May 07	91	—
72	,,	766	April—May	3	May 07	15	—
98	Rohtak	1494	June	1	April—June 07	32	—
63	Jhaggar	702	Feb.	1	April—June 07	26	—
114	Rohtak	519	Jan.—Mar.	47	April—May 07	5	35

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXVIII.

Shows the period during the epidemic of 1904—05 *in which* 31 *villages in Rohtak District infected the previous epidemic first reported plague deaths.*

	1904					1905				
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Number of villages infected in 1903—04 in which deaths were returned in 1904—05.	1	3	3	2	0	4	2	5	11	0
Total number of villages which returned deaths each month.	2	6	9	17	23	63	101	156	232	208

TABLE XXIX.

Shows the interval for which 31 *villages in Rohtak District infected in the epidemics of* 1903—04 *and* 1904—05 *did not report plague deaths.*

	Number of months in which no plague deaths were returned												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Number of villages	0	3	2	2	2	2	1	3	7	5	2	1	1

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXX.

Data referring to villages in Rohtak District infected in epidemic of 1905—06.

No. of village	Tehsil	Population	Details of infection of 1905—06: Months during which deaths were returned	Details of infection of 1905—06: No. of deaths	Details of infection of 1906—07: Months during which deaths were returned	Details of infection of 1906—07: No. of deaths	No. of months free from deaths
2	Gohana	2269	April—May 06	110	May—June 07	64	10
12	,,	1205	Feb.—May 06	172	May—June 07	23	11
45	,,	1291	Feb.—April 06	53	March—May 07	117	10
79	,,	1720	March—April 06	17	April—June 07	116	11
83	Rohtak	4727	April—May 06	3	Jan.—May 07	266	—
16	Gohana	7509	April—June 06	195	Feb.—June 07	609	7
33	,,	1521	March—May 06	68	March—May 07	175	9
47	,,	2470	April—May 06	39	Nov. 06—May 07	177	5
3	Rohtak	2948	April—May 06	6	April—July 07	93	10
15	Gohana	4068	Feb.—May 06	258	March—June 07	265	9
3	,,	2443	Dec. 05—April 06	68	May—June 07	26	12
31	,,	4241	May—June 06	55	Sept. 06—July 07	897	2
49	,,	4568	Feb.—May 06	337	Feb.—June 07	258	8
39	Rohtak	3838	April 06	4	Feb.—May 07	135	—
39	Gohana	5657	April—June 06	32	Oct. 06—July 07	245	3
11	Rohtak	5126	April—May 06	13	Aug. 06—June 07	234	2
48	Gohana	4115	May 06	11	Feb.—May 07	274	8
80	,,	2245	May 06	8	March—April 07	174	9
13	,,	3185	Jan.—March 06	35	April—June 07	206	10
112	Rohtak	9723	Jan.—May 06	257	March—June 07	65	9
85	,,	20,024	April—May 06	3	Feb.—June 07	463	—
93	Sampla	5316	April 06	1	Feb.—June 07	416	—
35	Rohtak	7640	Feb.—May 06	9	March—June 07	49	10
29	Gohana	1035	Jan. 06	2	April—June 07	17	—
32	Jhaggar	1104	April 06	1	April—May 07	43	—
21	Rohtak	3783	Jan.—March 06	29	March—June 07	574	11
11	Jhaggar	645	April—May 06	5	Nil	—	—
94	Rohtak	1735	April—May 06	38	Nil	—	—
106	,,	1214	May 06	4	Nil	—	—
104	Sampla	266	Oct. 05—Feb. 06	82	Nil	—	—

TABLE XXXI.

Shows the period during the epidemic of 1906—07 *in which* 20 *villages in Rohtak District infected the previous epidemic first reported plague deaths.*

	1906					1907				
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Number of villages infected in 1905—06 in which deaths were returned in 1906—07.	1	1	1	1	0	0	3	7	3	3
Total number of villages which returned deaths each month.	1	4	7	9	11	21	49	132	198	199

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXXII.

Shows the interval for which 20 *villages in Rohtak District infected in the epidemics of* 1905—06 *and* 1906—07 *did not report plague deaths.*

	Number of months in which no plague deaths were returned												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Number of villages	0	2	1	0	1	0	1	2	4	5	3	1	0

TABLE XXXIII.

Data referring to villages in Mozuffarnagar District infected in 1902—03 *epidemic as regards subsequent infection.*

Name	Population	Thana	Details of infection of 1902—03		Details of next infection		No. of months free
			Dates of first and last deaths	No. of deaths	Dates of first and last deaths	No. of deaths	
Chandan	97	Purkazi	30. 4. 03— 1. 5. 03	3	Nil	—	—
Yarpur	882	Thana-Bhavan	22. 3. 03—28. 3. 03	3	Nil	—	—
Sitheri	441	Budhana	5. 4. 03— 5. 4. 03	1	Nil	—	—
Mandkali	644	,,	4. 11. 02—28. 4. 03	59	3. 10. 04—14. 10. 03	10	17
Atawa	1445	,,	10. 2. 03—10. 2. 03	1	5. 11. 04—15. 11. 04	15	20
Barkali	561	,,	29. 11. 02—29. 11. 02	1	1. 5. 07— 7. 5. 07	15	53
Kherichangaim	779	Jansath	10. 5. 03—10. 5. 03	1	12. 5. 07—27. 5. 07	19	47
Tagain	681	Khatauli	14. 4. 03— 8. 5. 03	70	6. 2. 04—10. 2. 04	9	8
Chand-Samand	1163	,,	21. 4. 03—27. 4. 03	1	29. 3. 04— 7. 4. 04	27	10
Budma-Kalan	1742	Titavi	12. 3. 03—12. 3. 03	1	30. 2. 05—13. 5. 05	32	23
Basehra	4497	Purkazi	16. 4. 03— 8. 6. 03	69	12. 3. 05—31. 5. 05	172	20
Kadargarh	618	Thana-Bhavan	16. 9. 03—16. 9. 03	1	2. 1. 05—18. 3. 05	15	15
Majahadpur	1113	Khatauli	10. 4. 03— 2. 5. 03	16	14. 1. 05—15. 2. 05	57	19
Budhana	6664	Budhana	7. 3. 03— 7. 3. 03	1	21. 5. 05— 4. 6. 05	199	25
Bitanda	2663	,,	22. 11. 02—26. 4. 03	279	1. 9. 04— 3. 11. 04	30	16
Chandheri	694	,,	29. 11. 02—29. 11. 02	2	9. 5. 05—13. 5. 05	16	29
Kurthal	1823	,,	7. 4. 03—12. 5. 03	46	1. 10. 04—12. 10. 04	7	16
Baroda	2754	,,	4. 11. 02— 4. 11. 02	1	25. 4. 05—11. 6. 05	203	28
Khatauli	8695	Khatauli	13. 3. 03—10. 6. 03	11	23. 10. 03— 6. 4. 04	305	3
Ladpur	855	,,	12. 4. 03—12. 4. 03	1	8. 2. 04—29. 2. 04	37	9
Kalanda-Kalan	2140	,,	22. 4. 03—30. 5. 03	2	14. 11. 03—20. 11. 03	4	5
Meranpur	7209	Meranpur	26. 2. 03—26. 5. 03	150	31. 3. 04— 8. 6. 04	151	9
Kheri-Sarai	1443	,,	18. 4. 03—23. 5. 03	23	18. 4. 04—21. 4. 04	2	10
Amarpur	2294	Shahpur	10. 4. 03—29. 5. 03	21	11. 3. 04— 8. 5. 04	46	9
M. Nagar	23,444	M. Nagar	21. 2. 03—11. 6. 03	25	25. 10. 03—23. 4. 04	331	3

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXXIV.

Showing the interval during which 11 *villages in Mozuffarnagar District infected in* 1902—03 *and again in* 1903—04 *or subsequent epidemic did not report plague deaths.*

	Number of months during which no plague deaths were returned											
	1	2	3	4	5	6	7	8	9	10	11	12 & over
Number of villages	0	0	2	0	0	0	0	1	2	1	0	5

TABLE XXXV.

Showing the period during the epidemic of 1903—04 *in which* 6 *villages in Mozuffarnagar District infected the previous epidemic first reported plague deaths.*

	1903					1904				
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Number of villages infected in 1902—03.	0	0	2	0	0	0	1	2	1	0
Total number of villages which returned deaths.	0	0	2	5	7	11	30	51	91	52

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXXVI.

Data referring to villages in Mozuffarnagar District infected in 1905—06 *as regards subsequent infection.*

Name	Population	Thana	Details of infection in 1905—06		Details of next infection		No. of months free
			Dates of first and last deaths	No. of deaths	Dates of first and last deaths	No. of deaths	
M. Nagar	23,444	M. Nagar	8. 3. 06—11. 6. 06	112	5. 11. 06—23. 5. 07	480	4
Maulaheri	915	,,	21. 3. 06—27. 4. 06	9	21. 3. 07—19. 4. 07	36	10
Chandpur	1109	,,	4. 4. 06—20. 5. 06	12	30. 11. 06— 3. 2. 07	41	5
Pinna	2853	Titawi	22. 4. 06—24. 4. 06	3	26. 3. 07—18. 6. 07	135	10
Saidpurah	308	,,	22. 4. 06—22. 4. 06	1	8. 2. 07— 6. 3. 07	26	9
Harsauli	3069	,,	21. 1. 06—23. 4. 06	208	25. 3. 07—23. 5. 07	348	10
Bodhena Kurd	1046	,,	16. 3. 06—13. 4. 06	32	8. 3. 07— 5. 4. 07	53	10
Nirmani	1315	,,	11. 2. 06—11. 2. 06	1	5. 4. 07—24. 5. 07	141	13
Ghesa Khera	571	Charthawal	4. 2. 06— 4. 2. 06	1	Nil	—	—
Kutesra	3565	,,	5. 11. 05—23. 1. 06	140	8. 3. 07— 5. 6. 07	273	13
Debchand	557	,,	3. 5. 06— 3. 5. 06	1	5. 5. 07—12. 5. 07	12	11
Kasauli	1323	,,	9. 4. 06—11. 5. 06	36	20. 9. 06—20. 9. 06	1	3
Jauli	2579	Bhopa	27. 3. 06— 5. 6. 06	53	10. 11. 06—21. 5. 07	103	4
Belra	1809	,,	22. 3. 06— 6. 6. 06	100	24. 1. 07—17. 5. 07	128	6
Teora	2699	,,	10. 6. 06—10. 6. 06	1	1. 12. 06— 1. 12. 06	1	5
Bhukareri	6316	,,	8. 2. 06—13. 5. 06	356	20. 2. 07—23. 5. 07	295	8
Sikri	3026	,,	6. 5. 06—23. 5. 06	24	7. 11. 06—24. 4. 07	47	5
Gadla	1767	,,	3. 2. 06— 9. 5. 06	105	4. 3. 07—15. 5. 07	117	9
Chaurawala	1543	,,	15. 5. 06—23. 5. 06	4	21. 10. 06— 5. 11. 06	16	4
Allahabas	282	,,	4. 3. 06— 4. 3. 06	1	Nil	—	—
Shamli	7478	Shamli	24. 12. 05—17. 5. 06	96	5. 2. 07— 7. 6. 07	239	8
Karmali	1078	,,	10. 12. 05— 5. 4. 06	59	17. 1. 07—28. 3. 07	86	8
Lank	3863	,,	10. 2. 06— 9. 5. 06	190	28. 2. 07— 3. 6. 07	206	8
Balra	2503	,,	10. 2. 06—28. 5. 06	180	3. 4. 07— 3. 5. 07	162	10
Bhaju	2563	,,	12. 4. 06—12. 4. 06	4	22. 3. 07— 3. 6. 07	218	10
Lilohan	1765	,,	17. 3. 06—17. 3. 06	1	Nil	—	—
Karandah	1471	,,	5. 4. 06— 5. 4. 06	1	27. 4. 06— 7. 6. 07	128	11
Chaunsa	1088	,,	22. 3. 06—22. 3. 06	4	30. 5. 07—30. 5. 07	1	13
Bauchra	738	,,	5. 5. 06—25. 5. 06	30	23. 5. 07— 5. 6. 07	38	11
Kheri	2212	,,	2. 4. 06— 2. 4. 06	5	15. 5. 07— 3. 6. 07	38	12
Bahri	2438	,,	14. 3. 06— 5. 6. 06	98	3. 3. 07— 2. 6. 07	224	8
Haranwara	1581	Thana-Bhavan	15. 3. 06—25. 4. 06	47	28. 3. 07—13. 5. 07	123	10
Mustgarh	359	,,	21. 1. 06—23. 1. 06	6	13. 4. 07— 6. 5. 07	50	14
Thanabhawan	8861	,,	24. 4. 06—12. 5. 06	13	13. 2. 07— 7. 6. 07	719	8
Bhatu	356	Jhinjhana	1. 4. 06—28. 4. 06	13	28. 5. 07— 3. 6. 07	12	12
Bela Mazra	771	Chausana	10. 11. 05—13. 12. 05	11	27. 3. 07— 8. 5. 07	134	14
Dathera	1245	,,	13. 12. 05—13. 12. 05	1	7. 4. 07— 8. 6. 07	32	15
Kairana	19,304	Kairana	19. 4. 06—25. 4. 06	2	14. 2. 07—13. 6. 07	2136	9
Gogwan	1158	,,	28. 4. 06—28. 5. 06	32	7. 5. 07—21. 6. 07	67	11

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXXVI (*continued*).

Name	Population	Thana	Details of infection in 1905—06: Dates of first and last deaths	Details of infection in 1905—06: No. of deaths	Details of next infection: Dates of first and last deaths	Details of next infection: No. of deaths	No. of months free
Bharu	2694	Kairana	28. 5. 06—28. 5. 06	2	13. 4. 07— 3. 6. 07	189	10
Jansath	6507	Jansath	13. 8. 05—11. 6. 06	90	1. 12. 06— 8. 5. 07	268	5
Talra	1214	,,	19. 4. 06— 1. 5. 06	2	21. 12. 06— 3. 5. 07	169	6
Kawal	4268	,,	17. 3. 06—29. 5. 06	117	25. 1. 07— 5. 5. 07	295	7
Chitaura	1762	,,	24. 4. 06—15. 5. 06	23	23. 12. 06— 4. 6. 07	101	6
Kheri Ferozabad	983	,,	28. 3. 06—20. 5. 06	31	25. 4. 07— 8. 6. 07	145	10
Nagla Mubarik	538	,,	17. 4. 06—19. 5. 06	19	28. 4. 07— 3. 5. 07	21	10
Kamehra	1197	,,	3. 11. 05—15. 1. 06	53	14. 2. 07—13. 5. 07	171	12
Khilwara	416	,,	20. 3. 06— 5. 5. 06	41	28. 2. 07— 8. 3. 07	20	8
Bera Asa	1349	,,	14. 4. 06—23. 4. 06	2	23. 4. 07— 3. 6. 07	48	11
Baupara	1341	Khatauli	6. 4. 06—20. 4. 06	31	7. 4. 07— 3. 6. 07	166	11
Pur Bahani	4489	,,	2. 3. 06—16. 5. 06	128	3. 4. 07—30. 5. 07	247	10
Pura	805	,,	2. 2. 06—31. 5. 06	127	15. 1. 07— 7. 6. 07	80	7
Sandhera	1881	Meranpur	9. 4. 06— 6. 5. 06	59	2. 3. 07— 3. 4. 07	85	9
Tiraula	1286	,,	17. 5. 06—28. 5. 06	18	4. 3. 07— 7. 4. 07	58	9
Bhuma	1892	,,	17. 11. 05—17. 11. 05	1	27. 1. 07— 3. 6. 07	204	13
Mandwara	607	Budhana	4. 2. 06—14. 3. 06	54	1. 3. 07— 7. 5. 07	146	11
Warli	804	,,	23. 3. 06—21. 4. 06	27	28. 5. 07—28. 5. 07	2	12
Bahsana	201	,,	28. 3. 06—26. 4. 06	52	23. 4. 07— 3. 6. 07	24	11
Habibpur	825	,,	30. 3. 06— 8. 4. 06	24	22. 4. 07—12. 5. 07	47	11
Sarai	1148	,,	30. 3. 06—12. 5. 06	40	19. 4. 07— 3. 6. 07	49	10
Tanda Mazra	1086	,,	5. 4. 06—14. 5. 06	38	8. 4. 07— 3. 6. 07	48	10
Kandhla	11,563	Kandhla	14. 4. 06—25. 5. 06	52	20. 7. 06—14. 11. 06	9	1
Phagana	3236	,,	11. 5. 06—11. 5. 06	2	6. 6. 07— 6. 6. 07	2	12
Rampur Kheri	698	,,	13. 4. 06—13. 4. 06	6	Nil	—	—
Gujarpur	328	,,	21. 4. 06—21. 4. 06	3	Nil	—	—
Ailani	3796	,,	24. 4. 06—27. 4. 06	8	Nil	—	—
Khandrauli	2815	,,	11. 5. 06—11. 5. 06	4	15. 5. 07—17. 6. 07	36	11
Garhi Ram	1957	,,	19. 3. 06— 5. 4. 06	20	Nil	—	—
Loi	1905	,,	30. 10. 05—11. 12. 05	22	16. 3. 07— 7. 6. 07	114	14

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXXVII.

Showing the interval in months during which 53 *villages in Mozuffarnagar District infected in* 1905—06 *and again in* 1906—07 *did not report plague deaths.*

Number of months	0	1	2	3	4	5	6	7	8	9	10	11	12 & over
Number of villages	0	1	0	0	3	3	3	2	7	4	13	8	9

TABLE XXXVIII.

Showing the period during the epidemic of 1906—07 *in which* 53 *villages in Mozuffarnagar District infected in the previous epidemic first returned plague deaths.*

	1906						1907					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
Number of villages infected in 1905—06.	1	0	0	1	4	3	5	7	13	12	6	1
Total number of villages which returned deaths.	1	1	1	7	16	35	77	159	288	438	427	169

TABLE XXXIX.

Data of future plague infection of villages in Rohtak District infected at the end of each epidemic.

No. of village	Tehsil	Population	No. of deaths during epidemic	Month when last death took place	Date when next infected	No. of months free from deaths
		A.	End of epidemic of 1903—04.			
108	Rohtak	4076	296	July 04	Jan. 05	5
35	,,	7640	262	June 04	Jan. 05	6
31	,,	2463	180	,,	Mar. 05	8
99	,,	1193	30	,,	April 05	9
107	,,	4279	204	,,	April 05	9
112	,,	9723	519	,,	Oct. 04	3
29	Gohana	1035	31	,,	April 05	9
93	Sampla	5316	100	,,	Sept. 04	2
74	,,	5060	75	,,	Sept. 04	2
75	Jhaggar	645	23	,,	April 05	9
		B.	End of epidemic of 1904—05.			
79	Rohtak	1686	16	June 05	Mar. 07	20
33	,,	759	18	,,	Mar. 07	20
31	,,	2463	162	,,	April 07	21
23	,,	413	15	,,	Nil	—
39	,,	3838	154	,,	April 06	9
3	,,	2948	83	,,	April 06	9
35	,,	200	20	,,	Nil	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXXIX (*continued*).

No. of village	Tehsil	Population	No. of deaths during epidemic	Month when last death took place	Date when next infected	No. of months free from deaths
		B. End of epidemic of 1904—05 (*continued*).				
30	Gohana	3327	231	,,	Mar. 07	20
82	,,	1928	112	,,	April 07	21
33	,,	1521	110	,,	Mar. 06	8
47	,,	2470	100	,,	April 06	9
21	,,	1296	76	,,	Feb. 07	19
15	,,	4068	20	,,	Feb. 06	7
3	,,	2443	23	,,	Jan. 06	6
31	,,	4241	31	,,	April 06	9
6	,,	3310	452	,,	Feb. 07	19
28	,,	330	28	,,	Feb. 07	19
74	,,	1923	15	,,	Mar. 07	20
78	,,	930	106	,,	June 07	23
66	,,	1467	28	,,	April 07	21
36	,,	2735	148	,,	Mar. 07	20
32	,,	1113	26	,,	April 07	21
11	,,	1191	78	,,	Nil	—
65	,,	1623	19	,,	April 07	21
67	,,	3133	187	,,	Mar. 07	20
64	,,	2034	211	,,	April 07	21
4	,,	2415	121	,,	April 07	21
48	,,	4115	332	,,	Mar. 06	8
13	Gohana	3185	61	June 05	Jan. 06	6
19	Sampla	1431	176	July	April 07	20
33	Jhaggar	4006	39	June	May 07	22
181	,,	974	72	,,	Nil	—
19	,,	927	2	,,	Nil	—
144	,,	1181	61	,,	Nil	—
32	,,	1104	47	,,	April 07	21
194	,,	2469	84	,,	Nil	—
93	,,	956	36	,,	Nil	—
		C. End of epidemic of 1905—06.				
83	Rohtak	4727	3	May	Jan. 07	7
35	,,	7640	9	,,	Mar. 07	9
94	,,	1735	38	,,	Nil	—
11	,,	5126	13	,,	Jan. 07	7
106	,,	1214	4	,,	Nil	—
3	,,	2948	6	,,	April 07	10
112	,,	9723	257	,,	Mar. 07	9
16	Gohana	7509	195	June	Feb. 07	7
2	,,	2269	110	,,	May 07	10
31	,,	4241	55	,,	Sept. 06	2
39	,,	5657	32	,,	Oct. 06	3
11	Jhaggar	645	5	May	Nil	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XL.

Data referring to villages in Mozuffarnagar District infected at the end of each epidemic.

Name	Population	Thana	No. of deaths during epidemic	Month in which last death occurred	Date when next infected, month of first death	No. of months free
		I. 1902—1903.				
Mozuffarnagar	23,444	M. Nagar	25	June 03	Oct. 03	3
Basera	4497	Purkazi	69	,,	Mar. 05	20
Khatauli	8695	Khatauli	4	,,	Oct. 03	3
Amarpur	2294	Shahpur	21	May 03	Mar. 04	9
Chandan	97	Purkazi	3	,,	Nil	—
Tigain	681	Khatauli	70	,,	Feb. 04	8
Majahadpur	1113	,,	16	,,	Jan. 05	19
Meranpur	7209	Meranpur	150	,,	Mar. 04	9
Kheri-Sarai	1443	,,	23	,,	April 04	10
Kailavda Kalan	2140	Khatauli	1	,,	Nov. 03	5
Karthal	1823	Budhana	46	,,	Oct. 04	17
		II. 1903—1904.				
Tijalhera	2385	Purkazi	120	June 04	July 04	0
Gadla	1767	Bhopa	2	,,	Jan. 05	6
Belra	1809	,,	68	,,	July 04	0
Berahthra	1061	,,	25	,,	May 07	34
Tisa	3384	,,	29	,,	Sept. 04	2
Tandhera	1881	Meranpur	72	,,	Mar. 05	8
Sambalhera	2329	,,	93	,,	Nov. 04	4
Meranpur	7209	,,	151	,,	Aug. 04	1
Nayagind	1020	,,	2	,,	Mar. 07	32
Katka	830	Jansath	5	,,	Jan. 05	6
Kambera	1197	,,	40	,,	Nov. 05	16
Mubarik	538	,,	26	,,	April 06	21
Kawal	4268	,,	209	,,	Nov. 04	4
Pal	477	,,	4	,,	Feb. 07	31
Mahalki	1365	,,	40	,,	Mar. 05	8
Ahrora	484	,,	38	,,	Mar. 05	8
Gangdheri	1085	Khatauli	10	,,	Jan. 07	30
Kilaoda Kalan	2140	,,	2	,,	Dec. 04	5
Sudhan	510	,,	5	,,	Mar. 05	8
Lank	3863	Shamli	263	,,	Feb. 06	19
Balva	2503	,,	63	,,	Nov. 04	4
Purbalin	4489	Khatauli	67	,,	Dec. 04	5
		III. 1904—1905.				
Rahkra	1425	Bhopa	34	June 05	Feb. 07	19
Badharwala	343	M. Nagar	1	,,	May 07	22
Medpur	221	,,	1	,,	Nil	—

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XL (*continued*).

Name	Population	Thana	No. of deaths during epidemic	Month in which last death occurred	Date when next infected, month of first death	No. of months free
		III. 1904—1905 (*continued*).				
Sherpur	1156	M. Nagar	2	June 05	Mar. 07	20
Nirana	680	,,	20	,,	Mar. 07	20
Jaranda	1744	,,	26	,,	April 07	21
Berahasa	1349	Jansath	3	,,	April 06	9
Sekheri	1207	,,	5	,,	Feb. 07	19
Mahimmadpur	600	Khatauli	5	,,	April 07	21
Satheri	1828	,,	33	,,	Feb. 07	19
Sohangni	1827	,,	100	,,	April 07	21
Karandah	1532	Titawi	32	,,	Nil	—
Jafarpur	756	Thanabhawan	26	,,	Feb. 07	19
Jalabad	6822	,,	319	,,	Jan. 07	18
Nogal	276	,,	7	,,	April 07	21
Chirdeka	509	,,	23	,,	April 07	21
Babri	2438	Shamli	276	,,	Mar. 06	8
Banat	3590	,,	256	,,	Mar. 07	20
Titaauli	1180	,,	156	,,	Mar. 07	20
Shamli	7478	,,	149	,,	Dec. 05	5
Kaserwa Khurd	914	,,	47	,,	May 07	22
Phagana	3236	Kandhla	30	,,	May 06	10
Gangani	6401	,,	157	,,	Mar. 07	20
Parasauli	2198	,,	114	,,	Nil	—
Kharar	3385	Budhana	143	,,	April 07	21
Bari	1199	,,	25	,,	Nil	—
Raipur	552	,,	54	,,	Nil	—
Jaula	4691	,,	163	,,	May 07	22
Budhana	6664	,,	199	,,	Jan. 07	18
Baranda	2754	,,	203	,,	April 07	21
Karthal	1823	,,	81	,,	April 07	21
Atawa	1445	,,	96	,,	Nil	—
Nagwa	1859	,,	114	,,	Nil	—
Kairana	19,304	Kairana	94	,,	April 06	9
Un	4502	Jhanjnana	272	,,	April 07	21
		IV. 1905—1906.				
Belra	1809	Bhopa	100	June 06	Jan. 07	6
Jauli	2579	,,	53	,,	Nov. 06	4
Teora	2699	,,	1	,,	Dec. 06	5
Jansath	6507	Jansath	69	,,	Dec. 06	5
Mozuffarnagar	23,444	M. Nagar	112	,,	Nov. 06	4
Bahori	2323	Shamli	96	,,	Mar. 07	8

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XLI.

Data referring to villages in the Amritsar District infected at the end of each epidemic.

No.	Tehsil	No. of deaths in epidemic	Month when last death occurred	Month when next death occurred	Months remained free
		Epidemic of 1901—1902.			
57	Amritsar	42	July 02	April 03	8
143	,,	35	,,	Jan. 03	5
63	,,	2	,,	Nov. 03	14
241	,,	6	,,	May 03	9
113	,,	249	,,	Aug. 02	0
49	Tarn-Tarn	14	,,	Nov. 02	3
64	,,	70	,,	Feb. 03	6
170	Amritsar	130	June 02	Jan. 03	6
130	,,	12	,,	May 03	10
171	,,	41	,,	May 03	10
86	,,	25	,,	Jan. 03	6
196	,,	50	,,	Jan. 04	18
145	,,	21	,,	April 04	21
311	,,	140	,,	May 03	10
142	,,	31	,,	Jan. 07	54
77	,,	53	,,	Nov. 04	27
24	,,	3	,,	Feb. 04	19
97	Tarn-Tarn	27	,,	Mar. 03	8
213	,,	4	,,	April 03	9
34	,,	3	,,	April 04	21
46	,,	14	,,	Nov. 02	4
42	,,	2	,,	Nov. 02	4
19	,,	19	,,	April 04	21
67	,,	6	,,	Jan. 03	6
100	,,	7	,,	April 04	21
		Epidemic of 1902—1903.			
189	Amritsar	20	July 03	Nil	—
213	,,	15	,,	April 04	8
210	,,	12	,,	April 04	8
219	,,	13	,,	June 04	10
164	,,	30	,,	Dec. 04	16
266	,,	40	,,	Jan. 05	17
334	,,	10	,,	Jan. 05	17
200	,,	20	,,	Feb. 05	18
253	,,	40	,,	Jan. 05	17
27	,,	40	,,	Feb. 04	6
137	,,	32	,,	Dec. 04	16
288	,,	26	,,	May 04	9
342	,,	25	,,	Feb. 05	18
113	,,	293	,,	Aug. 03	0

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XLI (*continued*).

No.	Tehsil	No. of deaths in epidemic	Month when last death occurred	Month when next death occurred	Months remained free
		Epidemic of 1902—1903 (*continued*).			
323	Tarn-Tarn	27	July 03	Mar. 04	7
315	,,	185	,,	Mar. 05	19
233	,,	30	,,	Feb. 05	18
196	,,	195	,,	April 04	8
178	Ajnala	29	,,	Dec. 04	16
257	,,	50	,,	Dec. 04	16
160	,,	10	,,	Jan. 05	17
56	,,	25	,,	April 05	20
295	,,	25	,,	April 05	20
281	,,	100	,,	April 05	20
244	,,	3	,,	Nil	—
210	,,	70	,,	Oct. 04	14
276	,,	25	,,	May 07	45
161	,,	55	,,	May 04	9
131	,,	35	,,	Dec. 04	16
114	,,	8	,,	May 04	9
244–273	,,	90	,,	Mar. 04	7
267	,,	20	,,	Nil	—
		Epidemic of 1903—1904.			
232	Amritsar	111	July 04	Feb. 05	6
311	,,	326	,,	Dec. 04	4
5	,,	88	,,	Mar. 05	7
113	,,	1103	,,	Jan. 05	5
17	,,	233	,,	Jan. 05	5
112	Tarn-Tarn	135	,,	Feb. 05	6
42	,,	244	,,	April 05	8
143	,,	48	,,	Nil	—
240	,,	1	,,	Mar. 05	7
196	,,	85	,,	Mar. 05	7
270	Ajnala	138	,,	May 05	9
100	,,	62	,,	May 07	33
63	,,	16	,,	Mar. 07	31
91	,,	29	,,	April 07	32
		Epidemic of 1904—1905.			
287	Amritsar	134	July 05	April 06	8
113	,,	1073	,,	Aug. 05	0
17	,,	86	,,	April 06	8
5	Tarn-Tarn	101	,,	Mar. 06	7
142	,,	117	,,	April 07	20
267	,,	88	,,	June 06	10
300	,,	107	,,	April 07	20
241	,,	24	,,	Mar. 07	19

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XLI (*continued*).

No.	Tehsil	No. of deaths in epidemic	Month when last death occurred	Month when next death occurred	Months remained free
		Epidemic of 1904—1905 (*continued*).			
243	Tarn-Tarn	18	July 05	Mar. 07	19
264	,,	256	,,	May 06	9
321	,,	140	,,	Nil	—
286	,,	95	,,	Feb. 07	18
66	,,	214	,,	Jan. 06	5
59	,,	9	,,	Nil	—
281	,,	77	,,	Jan. 07	17
23	,,	26	,,	Nil	—
150	,,	175	,,	April 07	20
240	,,	144	,,	Nil	—
319	,,	47	,,	May 06	9
64	,,	165	,,	May 06	9
254	,,	159	,,	April 07	20
268	,,	86	,,	June 06	10
311	,,	278	,,	April 06	8
76	,,	5	,,	April 06	8
179	,,	213	,,	Mar. 07	19
326	,,	35	,,	Feb. 07	18
26	Ajnala	213	,,	Mar. 07	19
269	,,	54	,,	April 07	20
295	,,	58	,,	Feb. 07	18
81	,,	90	,,	April 07	20
303	,,	52	,,	April 07	20
267	,,	130	,,	Feb. 07	18
206	,,	16	,,	Nil	—
262	,,	87	,,	April 07	20
226	,,	12	,,	April 07	20
309	,,	86	,,	April 07	20
161	,,	70	,,	Mar. 07	19
251	,,	86	,,	May 07	21
235	,,	11	,,	Nil	—
		Epidemic of 1905—1906.			
279	Amritsar	25	July 06	Dec. 06	4
160	,,	1	,,	Feb. 07	6
232	,,	70	,,	Feb. 07	6
262	,,	113	,,	Nil	—
311	,,	202	,,	Mar. 07	7
296	,,	9	,,	Nil	—
5	,,	39	,,	Jan. 07	5
113	,,	1863	,,	Aug. 06	0
17	,,	30	,,	Jan. 07	5
225	,,	113	,,	April 07	8
197	Ajnala	11	,,	Jan. 07	5

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XLII.

Showing the interval of freedom from plague deaths enjoyed by villages in Rohtak District which were still infected at the end of the different epidemics.

	Number of months during which no plague deaths were returned												
	0	1	2	3	4	5	6	7	8	9	10	11	12 & over
1903—04.													
Number of villages	0	0	2	1	0	1	1	0	1	4	—	—	—
1904—05.													
Number of villages	0	0	0	0	0	0	2	1	2	4	0	0	20
1905—06.													
Number of villages	0	0	1	1	0	0	0	3	0	2	2	—	—

TABLE XLIII.

Showing the interval of freedom from plague deaths enjoyed by villages in the Mozuffarnagar District which were still infected at the end of the different epidemics.

	Number of months during which no plague deaths were returned												
	0	1	2	3	4	5	6	7	8	9	10	11	12 & over
1902—03.													
Number of villages	0	0	0	2	0	1	0	0	1	2	1	0	3
1903—04.													
Number of villages	2	1	1	0	3	1	2	0	4	0	0	0	8
1904—05.													
Number of villages	0	0	0	0	0	1	0	0	1	2	1	0	23
1905—06.													
Number of villages	0	0	0	0	2	2	1	0	1	0	0	0	0

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XLIV.

Showing the interval of freedom from plague deaths enjoyed by villages in the Amritsar District which were still infected at the end of the different epidemics.

	Number of months during which no plague deaths were returned												
	0	1	2	3	4	5	6	7	8	9	10	11	12 & over
1901—02.													
Number of villages	1	0	0	1	2	1	4	0	2	2	3	0	9
1902—03.													
Number of villages	1	0	0	0	0	0	1	2	3	3	1	0	18
1903—04.													
Number of villages	0	0	0	0	1	2	2	3	1	1	0	0	3
1904—05.													
Number of villages	1	0	0	0	0	1	0	1	4	3	2	0	21
1905—06.													
Number of villages	1	0	0	0	1	3	2	1	1	—	—	—	—

TABLE XLV.

Showing the total number of villages in Rohtak District and the number of villages infected in each epidemic.

	Number of villages infected			
Total No. of villages	1st epidemic 1903—04	2nd epidemic 1904—05	3rd epidemic 1905—06	4th epidemic 1906—07
499	57	285	30	249

TABLE XLVI.

Showing the actual number of villages in Rohtak District which were infected in no, one, two, three and four epidemics.

Number of villages infected in				
No epidemic	One epidemic	Two epidemics	Three epidemics	Four epidemics
145	138	172	37	7

TABLE XLVII.

Showing the calculated probable number of villages in Rohtak District which would have been infected in no, one, two, three and four epidemics if all villages were equally liable to infection in all four epidemics.

Number of villages infected in				
No epidemic	One epidemic	Two epidemics	Three epidemics	Four epidemics
89	225	159	24	1

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XLVIII.

Showing the total number of villages in Mozuffarnagar District and the number of villages infected in each epidemic.

Total No. of villages	Number of villages infected in				
	1st epidemic	2nd epidemic	3rd epidemic	4th epidemic	5th epidemic
973	25	130	313	69	579

TABLE XLIX.

Showing the actual number of villages in Mozuffarnagar District which were infected in no, one, two, three, four and five epidemics.

Number of villages infected in					
No epidemic	One epidemic	Two epidemics	Three epidemics	Four epidemics	Five epidemics
334	301	226	86	25	1

TABLE L.

Showing the calculated probable number of villages in Mozuffarnagar District which would have been infected in no, one, two, three, four and five epidemics if all villages were equally liable to infection in all five epidemics.

Number of villages infected in					
No epidemic	One epidemic	Two epidemics	Three epidemics	Four epidemics	Five epidemics
202	457	261	49	3	0·05

TABLE LI.

Showing the total number of villages in Amritsar District and the number of villages infected in each epidemic.

Total No. of villages	Number of villages infected in					
	1st epidemic	2nd epidemic	3rd epidemic	4th epidemic	5th epidemic	6th epidemic
1062	62	506	445	669	276	604

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE LII.

Showing the actual number of villages in Amritsar District which were infected in no, one, two, three, four, five and six epidemics.

Number of villages infected in						
No epidemic	One epidemic	Two epidemics	Three epidemics	Four epidemics	Five epidemics	Six epidemics
155	183	211	230	169	93	21

TABLE LIII.

Showing the calculated probable number of villages in Amritsar District which would have been infected in no, one, two, three, four, five and six epidemics if all villages were equally liable to infection in all six epidemics.

Number of villages infected in						
No epidemic	One epidemic	Two epidemics	Three epidemics	Four epidemics	Five epidemics	Six epidemics
48·5	195·8	329·1	295·1	148·8	40	4·5

TABLE LIV.

Showing the number of villages in Rohtak District infected each epidemic along with the total and average population.

Epidemic of	No. of villages infected	Total population of villages infected	Average population of villages infected
1903—1904	57	149,524	2623
1904—1905	285	493,145	1730
1905—1906	30	117,631	3921
1906—1907	249	471,670	1894

TABLE LV.

Showing the number of villages in Rohtak District with the total and average population infected in no, one, two, three and four epidemics.

	No. of villages	Total population of villages	Average population of villages
Never infected	145	63,051	435
Infected in one epidemic	138	109,491	793
Infected in two epidemics	172	270,986	1575
Infected in three epidemics	37	128,669	3478
Infected in four epidemics	7	48,625	6946
Total	499	620,822	1244

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE LVI.

Showing the number of villages in Mozuffarnagar District infected each epidemic, with their mean population.

No. and year of epidemic		No. of villages infected	Total population of villages infected	Mean population of villages infected
1st	1902—03	25	75,341	3014
2nd	1903—04	130	257,091	1978
3rd	1904—05	313	532,941	1703
4th	1905—06	69	183,270	2656
5th	1906—07	579	744,948	1286

TABLE LVII.

Showing the number of villages in Mozuffarnagar District with their mean population infected in no epidemic, in only one epidemic, in any two, in any three, in any four and in all five epidemics.

	No. of villages	Total population of villages	Mean population of villages
No epidemic	334	127,217	381
One epidemic	301	211,861	704
Two epidemics	226	284,843	1260
Three epidemics	86	187,300	2178
Four epidemics	25	83,231	3329
Five epidemics	1	23,444	23,444
Total	973	917,896	942

TABLE LVIII.

Showing the number of villages in Amritsar District infected each epidemic, with their mean population.

No. and year of epidemic		No. of villages infected	Total population of villages infected	Mean population of villages infected
1st	1901—02	63	269,467	4277
2nd	1902—03	506	734,753	1452
3rd	1903—04	445	682,138	1533
4th	1904—05	669	869,853	1300
5th	1905—06	276	510,464	1849
6th	1906—07	604	813,116	1346

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE LIX.

Showing the number of villages in Amritsar District with their mean population, infected in no epidemic, in only one, in any two, three, four, five, and in all six epidemics.

Infected in	No. of villages	Total population of villages	Mean population of villages
No epidemic	155	39,225	253
One epidemic	183	83,779	458
Two epidemics	211	125,899	597
Three epidemics	230	210,281	914
Four epidemics	169	206,547	1222
Five epidemics	93	155,971	1677
Six epidemics	21	217,888	10,376
Total	1062	1,039,590	978

TABLE LX.

Showing in Rohtak District for each Tehsil the number of villages and their percentage on the total villages infected in no epidemic, and in one, two, three and four epidemics.

	Rohtak Tehsil	Gohana Tehsil	Sampla Tehsil	Jhaggar Tehsil
Total no. of villages	109	79	124	187
Total population	195,423	140,682	160,262	124,455
Average population per village	1793	1781	1292	666
No. of villages never infected	21	6	21	97
Percent. of villages never infected	19·3	7·6	16·9	51·9
No. of villages inf. 1 epidemic	28	13	36	61
Percent. of villages inf. 1 epidemic	25·7	16·5	29	32·6
No. of villages inf. 2 epidemics	39	47	61	25
Percent. of villages inf. 2 epidemics	35·8	59·5	49·2	13·4
No. of villages inf. 3 epidemics	17	12	5	3
Percent. of villages inf. 3 epidemics	15·6	15·1	4	1·6
No. of villages inf. 4 epidemics	4	1	1	1
Percent. of villages inf. 4 epidemics	3·7	1·3	0·9	0·5

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

PART II. STATISTICAL ANALYSES OF DATA RESPECTING EPIDEMICS OF PLAGUE IN THREE DISTRICTS OF THE PUNJAB.

BY M. GREENWOOD, JR.

(*Statistician to the Lister Institute of Preventive Medicine.*)

First Report—*On the factors which influence the frequency of infection.*

It was decided to proceed with the analysis of the data collected by Major Lamb in the following stages:—

1. To determine whether the numbers of villages attacked in any one, two or more epidemics were in agreement with the numbers one would expect to find supposing the matter were merely one of chance.

2. In the event of such distributions not proving to be random, to attempt to account for the non-random character, paying special attention to the supposed importance of size of village in this connection.

3. In the event of the distribution being non-random, and its character not being explained by variations in the populations, to investigate the matter further.

4. To consider and report upon the variations in percentages of deaths which were manifest even in villages of approximately the same size.

Since many of the points referred to are of considerable importance and their statistical treatment will be a somewhat lengthy process, it will make for clearness and avoid unnecessary delay if I embody my results in a series of separate reports. In the present communication, I shall deal with factors which influence the recurrence of infections, in so far as I have been able to reach statistical results. I desire also to remark that I have attempted on this occasion, and shall endeavour in any subsequent communications, to explain intelligibly the analytical methods I employ. I do not mean by this that I propose to discuss the somewhat difficult mathematical considerations from which the methods in question were, as a matter of history, derived; but merely

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

that I hope to furnish sufficient explanation to place the reader in a position to judge for himself whether the processes employed and the conclusions stated are, or are not, justifiable.

The first point to be observed is that one must adopt some standard as to what constitutes an infected village. When, for instance, only a few cases of plague have been found in a large village, it may be that these have been imported and are no true indications of local morbidity. To decide this point is not the duty of a statistician, since it involves special knowledge only possessed by those familiar with local conditions. I have, for the purposes of the present inquiry, been instructed by those who have this knowledge to regard as an infected village any village from which a plague death has been reported; the effect of modifying this criterion may be matter for subsequent inquiry.

At the outset, it is apparent that the size of the village is an important factor in the likelihood of its being infected. This is almost axiomatic on any theory of aetiology and is abundantly demonstrated by the statistics of which Table I give merely a selection.

The next point is to consider whether this factor is alone responsible for the selective grouping of villages affected in various combinations of epidemics, but before examining this we must consider the analytical process to be used.

The problem is of the following nature—There are a villages in a district and plague infections have been reported in n different epidemics, c_1 in the first, c_2 in the second, and so on, up to c_n. We also know that a_n villages have been infected in all epidemics, a_{n-1} in $n-1$ of the epidemics, and so on. Supposing that the fact of being infected in any one year is quite independent of the fact of being affected in any other year, is the number of actual recurrences in agreement with what we should expect?

This problem may be approached in the following way. The chance of being affected in the first epidemic is $\frac{c_1}{a}$, of being affected in the second epidemic $\frac{c_2}{a}$, and so on. Therefore the chance of being affected in all epidemics is $\frac{c_1 c_2 c_3 \ldots c_n}{a^n}$ and the total number which should be so infected is $a \times \frac{c_1 c_2 c_3 \ldots c_n}{a^n}$. Thus the number which would be infected in the first three epidemics is $a \times \frac{c_1 c_2 c_3 d_4 d_5 \ldots d_n}{a^n}$ where

$$d_4 = a - c_4 \; d_5 = a - c_5 \text{ etc.}$$

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

And we shall find the number infected in any three epidemics by taking a times the sum of all such expressions as

$$\frac{c_1 c_2 c_3 d_4 d_5 d_6 \dots d_n}{a_n}.$$

In this way one obtains the most probable number of infections for each possible combination of epidemics and we next require some method of testing the agreement between the observed numbers and the calculated ones. Of the various tests which have been proposed the most satisfactory is that devised by Karl Pearson[1] which can, for our purposes, be looked at in the following simple way.

Supposing the observed value in any case is x and the value expected, on any hypothesis which we desire to test, y. Then $\frac{(x-y)^2}{y}$ will be a measure of agreement independent of sign and its summed value $S\frac{(x-y)^2}{y}$, for all the classes we have formed will be a measure of the total agreement. The problem now reduces itself to the following—How many times, on the average, will the observed values in a series of events which are known to follow a given law of distribution differ from the expected values owing to random sampling so as to produce a specified arithmetical value of $S\frac{(x-y)^2}{y}$?

This has been answered by Pearson in the memoir referred to and a table constructed by W. Palin Elderton[2].

For instance, suppose that in a certain case $S\frac{(x-y)^2}{y}$, or as it is usually termed χ^2, is equal to 10 and we find against this value for material grouped in the number of subdivisions used for our material, the fraction ·8. This means that if the law be true we should get, on repeating our observations, as bad an agreement as or a worse agreement than that given by our material, eight times out of ten. In other words it is most likely that the theoretical law assumed really describes the observations.

What value of P (the ·8 of my illustration is called P) should be taken as good evidence for the truth of one's hypothesis, is partly a

[1] "On the Criterion that a given System of Deviations from the Probable in the Case of a Correlated System of Variables is such that it can be reasonably supposed to have arisen from Random Sampling." K. Pearson, *Phil. Mag.*, 1900, Vol. L., p. 157.

[2] "Tables for Testing the Goodness of Fit of Theory to Observation." W. P. Elderton, *Biom.*, 1902, p. 155.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

matter of individual judgment and partly depends on the nature of the material examined. I should be disposed to regard any value of P greater than ·45 as good and greater than ·25 as fair evidence in such problems as those we have to consider now. I do not propose to examine the mathematical justification of the method I have outlined; reference can be made by those readers who are interested in the subject to the memoir of Pearson which I have cited. It is, I hope, sufficiently clear that the process lends itself to our particular investigation. Some practical difficulties now deserve notice.

Although the calculation of the probable number of villages to be infected in any combination of epidemics is, as I have shown, merely a matter of simple arithmetic, yet the arithmetic becomes extremely laborious when the number of epidemics under review is even moderately large. Thus in Amritsar district there are six epidemics and the complete evaluation of the various combinations of villages affected never, once, twice etc., requires the determination of 64 distinct products each composed of six terms. Without a mechanical calculator this is an impracticable task and even with such help it is very tedious. It may be asked whether an approximation to the value cannot be obtained by some easier method and a way out of the difficulty might seem to be afforded by using a mean value. Thus if c_1, c_2, c_3 etc. were infected in each year we might determine the mean probability of infection

$$\frac{c_1 + c_2 + c_3 + \ldots c_n}{na} = \text{say } \bar{p},$$

and, similarly, the mean probability of not being infected = say $\bar{q}$. Then the number which should be infected in any two years *e.g.* would be $a\,(\bar{p})^2\,(\bar{q})^{n-2}$. The objections to this simplification are, I think, insuperable. The total number of epidemics under observation is absolutely small and the proportion of villages attacked from epidemic to epidemic, varies enormously. For instance, in Amritsar, out of 1062 villages—

62	were	attacked in	1901—2
506	„	„	1902—3
445	„	„	1903—4
669	„	„	1904—5
276	„	„	1905—6
604	„	„	1906—7.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

The probable error of a mean determined from so short and variable a series is large (for *normally distributed variables*, the probable error of the mean is $\cdot 67449 \times \frac{\text{Standard Deviation}}{\sqrt{\text{Number of Observations}}}$).

The difference between the results obtained by calculating the probable numbers in both ways is appreciable as will be seen in Table II. I have therefore made all the calculations by the direct summation method already described. Although the process was very long it was rendered possible by the use of a large Brunsviga Calculator and all additions were checked with a Burroughs Adding Machine.

I shall give the complete working of one table, that for the whole Amritsar district. From the figures given above, we see that the chances of being infected in each year are:

$$p_1 = \cdot 0583804, \quad p_2 = \cdot 4764595, \quad p_3 = \cdot 4190207,$$
$$p_4 = \cdot 6299435, \quad p_5 = \cdot 2598870, \quad p_6 = \cdot 5687382,$$

and the corresponding chances of not being infected are:

$$q_1 = \cdot 9416196, \quad q_2 = \cdot 5235405, \quad q_3 = \cdot 5809793,$$
$$q_4 = \cdot 3700565, \quad q_5 = \cdot 7401130, \quad q_6 = \cdot 4312618.$$

With these values for the independent probabilities, we determine the expected number in each category. Thus the probable number affected five times is

$$1062\,(p_1p_2p_3p_4p_5q_6 + p_1p_2p_3p_4p_6q_5 + p_1p_2p_3p_5p_6q_4 + p_1p_2p_4p_5p_6q_3 + p_1p_3p_4p_5p_6q_2 + p_2p_3p_4p_5p_6q_1).$$

Finally we reach Table III the headings of which are explanatory. The value of P is so small that we can evidently not regard the distribution as a random one. Tables IV and V show similar results for the other two districts. Table III A gives the details for Amritsar.

We now come to the question whether the non-random character of these distributions is due to mixing together villages of very different sizes. I approached the problem in the following way. A series of groups was chosen, each containing villages falling within assigned limits of size. Each group was then treated in the manner just explained, the probability of infection in each epidemic being of course determined separately for each group. The results appear in Tables VI to XXV, the actual working details being omitted to save space. These tables merit somewhat close attention. In the first place it is obvious that the majority exhibit a much closer agreement between theory and

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

observation than could be discerned in the general Tables III to V, but an objection will immediately occur to the reader. Tables VI to XXV are sub-samples and consequently include far fewer observations than figure in the Tables III to V, is this the cause of the better agreement?

It is clear that the test of agreement which I have employed gives an answer which in some measure depends on the absolute size of the experience. Thus our criterion is the value of

$$S\frac{(x-y)^2}{y}=\chi^2.$$

If we multiply x and y by a constant k this becomes:

$$S\frac{k^2(x-y)^2}{ky},$$

or

$$S\frac{k(x-y)^2}{y}.$$

Hence if k is a proper fraction χ^2 is diminished and the apparent goodness of fit increased. This is, of course, in accordance with the demands of common sense. A deviation of, say, ten per cent. from the theoretical value when we examine, say, a sample of 100 would not be regarded as making so much against the theory as a ten per cent. difference when the sample was one of 1000.

Now it seemed to me that one could form a reasonable opinion as to whether the higher values of P in some of the groups are merely due to reduction in absolute size and not to reduction in the relative discrepancy between theory and practice, quite simply. I have taken each table of totals (III—V) and determined the value which P would take if the relations between observed and calculated values were not disturbed but the value of χ^2 reduced to what would be given by smaller total numbers of observations.

In the case of Amritsar, the values of χ^2 reduced to 153, 129, 390 observations are still so large as to give values of P less than one in a billion; even with a total of 45 (the smallest Amritsar Group) and using five classes instead of six, P only rises to ·0001. The Mozuffarnagar total reduced to 72, 82, 141 and 161 observations also gives P less than one in a million. Rohtak gives $P=·04$ when the total is reduced to 44 and $P=·01$ for 60 observations. While I admit the test to be a rough one, I can see no valid objection to it. I hold it to be certainly true that the improved agreement between theory and practice shown in many of the Tables VI—XXV is not to any serious

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

extent dependent on the reduction in numbers, as compared with Tables III—V alone. We are now in a position to assert that size of population is an important factor in determining whether a village is likely to be attacked by plague, and that elimination of this factor tends to bring the number of recurrent infections into agreement with a chance distribution, but a variety of collateral questions are raised by the analytical results. To begin with, there is not only a great difference in the results from the several districts, but between the returns for groups of the same district. Why is this? Taking the second point first, the most obvious explanation would seem to be that the groups are arbitrary and that the variations in size within each are not the same. There is no real reason to think that absolute size within the group has anything to do with the matter, because the *a priori* chance of being infected has been calculated separately for each group; it could only be a question of relative variation. I determined the mean population of each group, the mean square deviation from the mean, its square root (the Standard Deviation) and the percentage that the standard deviation was of the mean (the Coefficient of Variation). These constants are shown in Tables VI to XXV and are collected together in Table XXVI. Taken as a whole, there appears to be a *slight* tendency for the higher values of P to be associated with smaller coefficients of variation and this was to some extent confirmed by determining the correlation between the value of P and the size of the coefficients of variation. I cannot, however, attribute any real importance to these findings. The figures marked with an asterisk are hardly comparable with the others since the variation depends mainly on the inclusion of a few very large or very small villages or towns. But if we exclude these, the variation is rarely in excess of 10. Now the census from which the populations were obtained was taken in 1901 and I understand that a variety of local circumstances prevent the census returns being very accurate (as a basis for estimating the present population). I was advised that one could not safely regard the error as being much less than ten per cent. In other words the variation within the groups is of the same order as the error in the estimates of population and cannot serve as a basis for valid statistical deductions. I am, therefore, of opinion that we cannot attribute the differences in the values of P to this factor. I must not of course be understood to mean that differences in size-variation have not played a part, but merely as stating that we have no reliable evidence that such is the case.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

A contributory influence of appreciably greater weight is the difference in number of villages within each group, especially as in some of the smaller groups fewer subdivisions were made owing to the calculated numbers of infections in five and six epidemics being very small. I have tested this in the same way as in comparing totals with groups (vid. supr.). Table XI gives $P = \cdot 07$ for 129 villages and this rises to ·57 for 44 observations. Table X gives $P = \cdot 148$ when we reduce the number of categories from 6 to 5 and the total to 44. Similarly, Table IX reduces to $P = \cdot 24$ and Table VIII to $P = \cdot 275$. Using the Mozuffarnagar results we find, reducing to a total of 44 and five categories (which enables us to compare with the Rohtak figures), Table XVI gives $P = \cdot 44$, Table XIV, $P = \cdot 08$, Table XV, $P = \cdot 21$.

These results show quite clearly that the size of the group and the number of sub-classes, whether 7, 6, or 5, employed, have had a considerable share in causing diversity within each district. They also show that the greatly improved fit among the Rohtak Groups as compared with Mozuffarnagar and especially Amritsar, is *partly*, but only partly accounted for, by the differences mentioned. We have seen that in one group only out of the Amritsar set have we been able to bring up the goodness of fit to the general level of the Rohtak returns. The same remark applies but with appreciably less force to a comparison between Mozuffarnagar and Rohtak. Table XXVIII contains all the Rohtak groups which were calculated in five classes reduced to a total of 44 and all the returns from the other districts reduced to the same dimensions. It will be found to support the preceding observations to the effect that Amritsar shows definitely less good agreement with expectation than do the other districts. The averages for each district are simple means formed without weighting with the numbers which actually appeared in each group; it is hardly possible to give truly comparable means because of the difficulty of assigning proper weights.

It therefore results, I think, that while careful allowance is to be made for the various sources of fallacy which are involved in attempting such comparisons as these, possibilities of error which I have not—consciously at least—minimised, there is an appreciable difference between the returns for any one district within that district and a still more appreciable difference between the returns for Amritsar on the one side and Rohtak on the other.

In the case of Rohtak, the general run of values for P is so good that we seem entitled to conclude that size of village has been by far the most important factor in producing the want of agreement which

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

is seen in the general Table. Other factors may have contributed to the results but their importance would seem to have been relatively small.

In Mozuffarnagar more hesitation is appropriate, but the fit in some important cases is so good that we are still justified in assigning the pre-eminence to the size factor[1]. In Amritsar, although certainly one and possibly two examples prove that size has been of considerable importance, yet the general trend of the tables seem to force one to the conclusion that something else has had a special influence not to be discerned in the other districts. What this something else is, I do not see my way to deciding on the strength of the information before me. A study of the maps and of the extremely interesting written descriptions with which I was furnished appear to show certain differences. Rohtak appears to be less thickly peopled than Amritsar[2]; Amritsar is somewhat better served by means of communication and possesses much larger and more important towns. Nothing which I have been able to find in the report of the Commissioners or in such descriptions of plague epidemiology as I have consulted, has suggested anything capable of statistical analysis with respect to these points.

The following ideas have occurred to me. Amritsar is much the largest city in the three districts and its intercourse with other towns and villages in the district must be great even out of proportion to its size, since it is the centre of important administrative business and is of religious interest to the Sikhs. The main lines of migration to and from the city are presumably not random, just as we find in England that of two apparently equally convenient highways between large towns one is much the more often traversed. Villages lying along the habitual lines of travel might be specially prone to importation of sources of infection irrespective of their size or other local peculiarities. The difficulty of testing this statistically lies in the fact that even in Amritsar size plays a part in the recurrence or non-recurrence of infections, but still the matter might be tested and I will do so[3], unless

[1] It may, perhaps, be asked why, in view of Table XXVIII, I class Mozuffarnagar rather with Rohtak than with Amritsar. The answer is that, apart from the rough nature of the test which Table XXVIII exemplifies, certain of the groups in Mozuffarnagar, notably Table XII with a relatively large number of included villages, exhibit a fairly close agreement between expectation and observation. In all the circumstances, I think this fact should have weight. The reader will of course draw his own conclusions.

[2] Rohtak ·3 per acre, Amritsar 1 per acre. I have no record of the area of Mozuffarnagar District.

[3] A preliminary analysis shows that the Amritsar villages within two miles of the line of railway are not a random sample of the total in respect to plague recurrence.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

those whose practical knowledge of the aetiological problem is far greater than mine, decide that the idea is baseless.

Another point which might be worth consideration is the possibility that the greater percentage of Sikh inhabitants, who are, I understand, more numerous in the Amritsar district than elsewhere, is of some significance.

One other conclusion seems to be supported by the statistical evidence. In investigating the arithmetical cause of the poor agreement between expectation and observation in Amritsar district, I was struck by the fact that the main discrepancy was often due to the calculated number of never-infected villages falling short of the observed number. To see whether this were really so, I constructed Table XXVII. It will be seen that in the majority of cases, notably in Amritsar, the observed excess in the first group has been largely responsible for the poor fit. It might be hastily assumed that this is due to taking an arbitrary standard of plague infection, viz. the occurrence of a single death. This is not necessarily or even probably the case. The number of such villages is not very large and were it large the *a priori* probability of non-infection would be greatly increased by including the villages with one or two deaths in the never-infected class. This would disturb the balance altogether and might conceivably make the agreement even worse. This is a point I can test, if the Committee so desire; as the case stands, I am disposed to conclude that certain villages, for reasons which do not appear in the mere statistics, are peculiarly difficult to infect.

Since the question as to whether a village infected in one year is, *ipso facto*, more likely to become infected in the next following year has a special bearing on the problem of importation as contrasted with recrudescence, I have investigated the point separately in the following way.

Six groups of Amritsar villages were chosen, viz.

(1) Villages of populations 1200—1400.
(2) „ „ 1000—1200.
(3) „ „ 800 —1000.
(4) „ „ 500 — 700.
(5) „ „ 400 — 500.

The numbers infected in the years 1904, 1905, 1906, 1907, were ascertained and then the numbers expected to be attacked in any pair of consecutive years were calculated on the assumption of equal incidence within the groups.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

The actual numbers were then compared with the calculated figures for each group and each pair of years. The goodness of agreement was then measured by the method used in other sections of this report. The results are collected in Table XXIX.

These results merit careful attention. It will be noticed that for the years 1904—5 and 1905—6, the agreement as measured by the value of P is extremely close, very fair for 1903—4, and moderate or poor (in view of the total number of observations) for 1906—7. The agreement obtained when the totals are used and grouped in years may be considered moderate.

On looking at the details, we notice that the agreement is, in general, worse in the groups within which the relative variations in size are largest. Thus the groups of big villages agree quite well in all cases but one and the poor agreement in the table for 1906—7 is mainly due to the group 500—700, while the fit for 1903—4 is appreciably diminished by the same group. It must, however, be carefully observed that this particular group is the largest and should have the most weight assigned to it. It must also be noticed that the actual numbers are, in the majority of cases, larger than the calculated ones and that where the agreement is best the likelihood of failure is least.

Let us next consider what sort of results we should expect to get, if we were to adopt an hypothesis as to epidemic origins.

If we hold that a plague outbreak depends on the recrudescence or bursting into activity of infective agencies left over from the last epidemic, then the following deductions are, in my opinion, inevitable. Only villages which have been attacked previously, in some shape or form, can *ex hypothesi* be attacked again. All those which have been so evidently infected as to report at least one death will be eligible for reinfection. In addition there will be some villages so slightly affected or placed under such unfavourable circumstances for the obtaining of exact information that they do not figure in our returns but which are eligible for attack in the following year. We should not, therefore, be surprised to find that *a very small proportion* of the villages which showed cases in any one year had not been *ostensibly* affected in the previous year. Unless, however, we assume that in two consecutive outbreaks the first is always much milder than the second, an assumption without evidence in its favour, the magnitude of this error cannot be sufficient to vitiate the general statement that the brunt of the second outbreak must be borne by villages affected in the first year. One would therefore expect a marked discrepancy between the number of

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

villages twice infected and the number calculated on the assumption that the infections in two years are independent events. Of course when a very large proportion of the villages is infected in both years, the possibility of a discrepancy is diminished. For instance, suppose in a group of 100 villages, 90 are infected in one year and 90 again in the second, we should expect as a matter of chance that 81 would be infected in both years and on the recrudescence hypothesis we could not have many more than 90 affected twice. Such a discrepancy as this, when the numbers are small, would be consistent with a high value of *P*. While these considerations must be well weighed, it seems to me that sufficient margin exists in the groups of villages and sequences of epidemics analysed in the table to have afforded scope for the numbers of twice affected villages to exceed the calculated numbers more definitely than was actually the case. To make this clear Table XXX was prepared.

This table shows the percentage of villages in each group affected in each epidemic, which did not return cases in the previous epidemic. This shows how large a proportion of villages affected in any one year had not returned cases in the previous year (vide supra p. 363).

It therefore seems clear that the agreement between the chance distribution and the actual one is closer than we should expect were the recrudescence hypothesis actually to express an epidemiological truth.

On the other hand, if we adopt the hypothesis of importation examined in the first part of this report, we should not expect to find an absolute agreement between chance and observation, we should still expect the fact of previous infection to have some importance, for the following reasons.

What the factors may be which determine importation has not yet been rendered precise. That habitual lines of travel, *e.g.* railways, are influential is suggested by many facts, especially the maps published by Nathan in his report of the 1896 outbreak and an analysis of the plague history of Amritsar villages within two miles of a railroad which I shall publish in a subsequent report. But, in any case, it may be regarded as certain that the influences of whatever nature tend to act in the same direction for fairly long periods of time, that if any village is favourably situated for importation in 1906 it is likely to be favourably situated again in 1907. Hence, we should expect to find that villages which have been infected once are on the whole more likely to be infected in the following epidemic than villages taken at random. But

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

since these circumstances are external to the village, and not part and parcel of the infection itself, they *may* be changed. A virulent outbreak in one year may deter visitors from approaching it in the following plague season, sanitary measures may be enacted and enforced, these and a thousand other circumstances dependent on the mutability of human actions might tend to weaken or even reverse the presumption created by a first infection. The conclusion is that while on the recrudescence theory we should expect to find a strong predisposition to reinfection in the case of villages once attacked, on the theory of reimportation, the influence of a first infection should be slighter and variable. The statistical evidence is, I think, more consistent with the second alternative.

In view of the smallness of the experience—from a statistical point of view—and the non-uniformity of the results, I am not justified in asserting that the evidence here adduced disproves the recrudescence theory. It does, however, somewhat strengthen the case against it. When this evidence is combined with that advanced in the first part of the present report, the case becomes, in my opinion, a rather strong one.

The broad conclusions which may be drawn from the present analysis are, I think, the following:—

(1) In none of the three districts can the total distribution of villages into classes showing no, one, two, etc. infections possibly be regarded as a chance event.

(2) In Rohtak, grouping villages of approximately the same size together and considering these groups separately, markedly diminishes the non-random character of the distribution. The agreement between the numbers in each group which were 0, 1, 2, 3 or 4 times affected and the numbers calculated on the assumption that the distribution was a chance one is in every case fair and in some excellent. This agreement is exaggerated by the relatively small numbers of villages in the groups and paucity of epidemics in comparison with the other districts, but when allowance is made for these circumstances, it is still evident that Rohtak yields better agreements than the other districts, in particular much better agreements than in the Amritsar groups.

(3) The Mozuffarnagar groups also show marked improvement as compared with the total for that district, an improvement not accounted for by the smaller size of the groups as compared with the total. They do not yield such uniformly good results as Rohtak but some are so excellent as to warrant one in concluding that size of villages in

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

Mozuffarnagar as in Rohtak is much the most important cause of the discrepancy found in the table for the whole district.

(4) Grouping in Amritsar has improved the agreement sufficiently to warrant the assertion that here also size of village has been of importance. The results, however, are not generally good and cannot, by allowing for size and number of classes, be sufficiently improved to justify us in regarding size of village as having played so decisive a part as in the other districts.

(5) Nothing in the statistical evidence affords a satisfactory explanation of this difference which may, however, profitably be made the object of further statistical inquiry.

(6) Differences in the numbers of villages within each group partly account for the differences in goodness of agreement within each set of groups, but not entirely.

(7) There is not sufficient statistical evidence that relative variations in size within the groups account for this divergence.

(8) There is no good reason to think that the fact of a village having been infected in one epidemic renders it more likely to be infected in the following epidemic or less likely to be so infected than any other village.

It may perhaps seem to the reader that the analysis here presented is not fine enough to do justice to the valuable material. While I fully recognise that the present data in all probability constitute the most valuable and complete statistical materials which have ever been collected for the study of plague, still, possible sources of error which have been pointed out to me, especially by Major Lamb, dispose me to think that an ostensibly more refined analysis might be misleading. The conclusions herein presented may not be altogether without interest and value.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE I.

To show the increase in percentage of infected villages as the population increases.

[Cf. the Tables LIV—LIX *supra*.]

Mean population of Groups	Percentage never infected	Percentage 1 infection	Percentage 2 infections	Percentage 3 infections	Percentage 4 or more infections
		Rohtak.			
92	80·00	20·00	0	0	0
257	51·22	31·71	17·07	0	0
352	50·00	33·33	14·67	0	0
603	30·65	32·26	32·26	4·84	0
784	20·93	39·53	34·88	4·65	0
1059	15·25	33·90	45·76	1·69	3·39
1465	6·82	25·00	61·36	6·82	0
2373	5·13	15·38	64·10	15·38	0
		Mozuffarnagar.			
404	34·76	45·12	17·68	1·22	1·22
606	25·53	45·39	23·40	5·67	0
917	21·58	28·06	38·13	10·79	1·44
1247	9·76	23·17	45·12	18·29	3·66
1746	6·94	23·61	40·28	23·61	5·56
4137	4·49	15·73	33·70	29·21	16·85
		Amritsar.			
175	37·78	24·44	28·89	4·44	4·44
276	24·53	30·19	18·87	20·75	5·66
308	21·88	33·13	23·75	15·00	6·25
708	7·44	20·51	22·05	29·49	20·51
1257	1·96	7·19	11·76	27·45	51·63
3837	0·78	2·33	4·65	18·60	73·64

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE II.

To show the difference between the results obtained by the direct method of calculation used in the other tables and the values obtained when a mean value for the probability of infection is used.

Amritsar District.

Number of epidemics	Villages infected (calculated numbers)	
	Direct method	Mean method
0	36	48·5
1	182	195·8
2	351	329·1
3	323	295·1
4	143	148·8
5	26	40
6	1	4·5

TABLE III.

Numbers of villages affected in various combinations of epidemics compared with the expected numbers.

Amritsar District.

Times affected	Actual number of villages	Calculated number of villages	Difference	Square of the difference	Square of the difference divided by the calculated number
0	155	36	+119	14161	393·36
1	183	182	+1	1	·01
2	211	351	−140	19600	55·84
3	230	323	−93	8649	26·78
4	169	143	+26	676	4·73
5	93	26	+67	4489	172·65
6	21	1	+20	400	400
	1062	1062			$1053{\cdot}37=\chi^2$

P corresponding to $\chi^2=1053{\cdot}37$ is too small to be tabled in Elderton's Table. Calculation from the Subsidiary Table shows P to be much less than one in a billion. In other words, if the distribution is really a chance one, we should get so bad an agreement on the average less than once in a billion trials. The distribution can hardly, therefore, be regarded as a chance one.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE III *A*.

Showing the details for various years.

Amritsar District.

Number of villages affected in various epidemics and combinations of epidemics together with the calculated probable numbers.

	Actual number	Probable number
1901	1	2·2
1902	34	32·7
1903	26	25·9
1904	60	61·1
1905	3	12·6
1906	59	47·4
	183	181·9
1901 & 2	1	2·0
1901 & 3	1	1·6
1901 & 4	2	3·8
1901 & 5	1	0·8
1901 & 6	1	2·9
1902 & 3	15	23·6
1902 & 4	30	55·6
1902 & 5	6	11·5
1902 & 6	22	43·1
1903 & 4	23	44·1
1903 & 5	9	9·1
1903 & 6	13	34·2
1904 & 5	16	21·5
1904 & 6	65	80·7
1905 & 6	6	16·6
	211	351·1
1901 & 2 & 3	1	1·5
1901 & 2 & 4	0	3·5
1901 & 2 & 5	0	0·7
1901 & 2 & 6	0	2·7
1901 & 3 & 6	3	2·1
1901 & 4 & 6	2	5·0
1901 & 5 & 6	0	1·0
1901 & 3 & 5	0	0·6
1901 & 3 & 4	0	2·7
1901 & 4 & 5	0	1·3
1902 & 3 & 6	14	31·1
1902 & 3 & 4	33	40·1
1902 & 3 & 5	4	8·3
1902 & 4 & 5	10	19·5
1902 & 4 & 6	79	73·4
1902 & 5 & 6	4	15·1
1903 & 4 & 5	5	15·5
1903 & 4 & 6	44	58·2
1903 & 5 & 6	6	12·0
1904 & 5 & 6	25	28·3
	230	322·6
1901 & 2 & 3 & 4	1	2·5
1901 & 3 & 4 & 5	1	1·0
1901 & 2 & 4 & 5	0	1·2
1901 & 2 & 3 & 5	0	0·5
1901 & 2 & 3 & 6	1	1·9
1901 & 2 & 4 & 6	2	4·5
1901 & 2 & 5 & 6	0	0·9
1901 & 3 & 5 & 6	0	0·7
1903 & 4 & 5 & 6	23	20·4
1903 & 2 & 5 & 6	7	10·9
1901 & 3 & 4 & 6	4	3·6
1902 & 4 & 5 & 6	30	25·8
1901 & 4 & 5 & 6	1	1·7
1902 & 3 & 4 & 6	82	52·9
1902 & 3 & 4 & 5	18	14·1
	170 (169)*	142·6
1901 & 2 & 3 & 4 & 5	2	0·9
1901 & 2 & 3 & 4 & 6	12	3·3
1901 & 3 & 4 & 5 & 6	1	1·3
1901 & 2 & 4 & 5 & 6	2	1·6
1902 & 3 & 4 & 5 & 6	79	18·6
1901 & 2 & 3 & 5 & 6	0	0·7
	96 (93)*	26·4
1901 & 2 & 3 & 4 & 5 & 6	21	1·2
Never affected	155	36·0
Totals	1066 (1062)	1061·8

* The figures in brackets are those which appear in the MS. summary handed me and I used them for calculation. They do not agree exactly with the returns in the data papers, but the difference is quite unimportant.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE IV.

MOZUFFARNAGAR DISTRICT.

Numbers of villages affected in various combinations of epidemics compared with the expected numbers.

Times affected	Actual number	Calculated number	Difference	Square of the difference	Square of the difference divided by the calculated number
0	334	209·60	+124·4	15475·36	73·832
1	301	461·268	−160·268	256858·3182	556·853
2	226	254·486	− 28·486	811·4522	3·189
3	86	44·866	+ 41·134	1692·00596	37·712
4	25 } 26	2·734 } 2·779	+ 23·221	539·2148	194·032
5	1 }	·045 }			
	973	972·999			865·61880

P less than 1 in a billion.

TABLE V.

ROHTAK DISTRICT.

Numbers of villages affected in various combinations of epidemics compared with the expected numbers.

Times affected	Actual number	Calculated number	Difference	Square of the difference	Square of the difference divided by the calculated number
0	145	89·26	+55·74	3106·9476	34·808
1	138	225·00	−87·00	7569·0	33·640
2	172	159·22	+12·78	163·3284	1·026
3	37	24·56	+12·44	154·7536	6·301
4	7	0·98	+ 6·02	36·2404	36·980
	499	499·02			112·755

P less than 1 in a billion.

TABLE VI.

AMRITSAR VILLAGES OF POPULATION BETWEEN 150 AND 200.

Comparison of actual and probable numbers affected.

Number of attacks	Actual numbers	Probable numbers
0	17	11·82
1	11	18·50
2	13	11·10
3	2	3·15
4	1 }	0·46
5	1 }	
	45	45·03

$P = ·156$.

Mean Population 175, Standard Deviation 13·94, Coefficient of Variation 7·97.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE VII.

AMRITSAR VILLAGES OF POPULATION BETWEEN 250 AND 300.

Comparison of actual and expected number of attacks.

[One village only was affected in the first year of plague so that for convenience of calculation this year has been regarded as free.]

Number of attacks	Actual number of villages affected	Expected number	
0	13	8	
1	16	19·17	
2	10	17·21	
3	11	7·16	
4	3	1·36	1·456
5	0	·096	
	53	52·996	

$P = ·035$.

Mean Population 276, Standard Deviation 14·16, Coefficient of Variation 5·13.

TABLE VIII.

AMRITSAR VILLAGES OF POPULATION BETWEEN 200 AND 400.

Comparison of actual and calculated numbers attacked in various epidemics.

Number of epidemics	Actual number		Expected number	
0	35		23·65	
1	53		58·29	
2	38		52·18	
3	24		21·40	
4	6	10	3·89	4·08
5	4		·18	
6	0		·01	
	160		159·6	

$P = ·001$.

Mean Population 308, Standard Deviation 62·94, Coefficient of Variation 20·41.

TABLE IX.

AMRITSAR VILLAGES OF POPULATION BETWEEN 400 AND 1000.

Comparison of expected attacks with actual attacks.

Number of epidemics	Observed		Expected	
0	29		11·9	
1	80		64·61	
2	86		130·06	
3	115		121·49	
4	63		52·77	
5	16	17	8·78	9·01
6	1		0·23	
	390		389·84	

P less than ·0000001.

Mean Population 708, Standard Deviation 177·97, Coefficient of Variation 25·13.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE X.

AMRITSAR VILLAGES OF POPULATION BETWEEN 1050 AND 1600.

Comparison of numbers actually affected with expectation.

Number of epidemics	Actual number affected		Expected number	
0	3	14	0·32	4·7
1	11		4·38	
2	18		21·64	
3	42		49·27	
4	46		52·59	
5	27		22·56	
6	6		2·19	
	153		152·95	

$P = \cdot 000031.$

Mean Population 1257, Standard Deviation 172·86, Coefficient of Variation 13·75.

TABLE XI.

AMRITSAR VILLAGES OF POPULATION GREATER THAN 1600.

Comparison of numbers affected in various epidemics with the calculated numbers.

Number of epidemics	Actually affected		Expected number	
0	1	10	0·015	5·425
1	3		0·15	
2	6		5·26	
3	24		25·29	
4	42		53·29	
5	44		39·15	
6	9		5·92	
	129		129·08	

$P = \cdot 07.$

Mean Population 3837, Standard Deviation 14065·42, Coefficient of Variation 366·61.

[This group includes Amritsar town.]

TABLE XII.

MOZUFFARNAGAR VILLAGES 350—500.

Comparison of actual numbers affected in various epidemics with expected numbers.

Number of attacks	Actual number		Expected number	
0	57		50·87	
1	74		82·90	
2	29		27·63	
3	2	4	2·54	2·6
4	2		0·06	
	164		164·0	

$P = \cdot 48.$

Mean Population 404, Standard Deviation 58·75, Coefficient of Variation 14·54.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XIII.

MOZUFFARNAGAR VILLAGES 500—750.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of times affected	Actual number	Expected number
0	36	28·11
1	64	76·05
2	33	32·75
3	8	3·82
4	0	0·18
5	0	0·003
	141	140·91

$P = \cdot 11$.

Mean Population 606, Standard Deviation 64·57, Coefficient of Variation 10·65.

TABLE XIV.

MOZUFFARNAGAR VILLAGES BETWEEN 750 AND 1100.

Comparison of actual numbers of cases with expectation.

Number of attacks	Actual number of villages	Expected number	
0	30	15·12	
1	39	62·74	
2	53	48·97	
3	15	11·43	
4	2	0·81	·82
5	0	0·01	
	139	139·08	

$P = \cdot 000007$.

Mean Population 917, Standard Deviation 100·61, Coefficient of Variation 10·98.

TABLE XV.

MOZUFFARNAGAR VILLAGES BETWEEN 1100 AND 1450.

Comparison of numbers actually affected in different epidemics with expected numbers.

Number of times affected	Actual number affected	Expected number	
0	8	3·02	
1	19	25·12	
2	37	38·51	
3	15	13·79	
4	3	1·61	1·66
5	0	0·05	
	82	82·1	

$P = \cdot 03$.

Mean Population 1247, Standard Deviation 100·21, Coefficient of Variation 7·73.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XVI.

MOZUFFARNAGAR VILLAGES BETWEEN 1400 AND 2200.

Comparison of numbers actually affected in various epidemics with the expected numbers.

Number of epidemics	Actual number	Expected number
0	5	2·19
1	17	17·78
2	29	34·14
3	17	15·71
4	4	2·12
5	0	0·07
	72	72·01

$P = \cdot 28$.

Mean Population 1746, Standard Deviation 188·85, Coefficient of Variation 10·81.

TABLE XVII.

MOZUFFARNAGAR VILLAGES OVER 2000.

Comparison of numbers actually affected in various epidemics with calculated numbers.

Number of epidemics	Number actually affected	Calculated number
0	4	0·94
1	14	8·39
2	30	36·56
3	26	30·47
4	14	12·08
5	1	0·57
	89	89·01

$P = \cdot 0064$.

Mean Population 4137, Standard Deviation 3146·29, Coefficient of Variation 76·05.

[Includes villages of population 11,563, 19,304, 23,444.]

TABLE XVIII.

ROHTAK VILLAGES 1—200.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of epidemics	Observed number	Expected number
0	40	40·5
1	10	9·0
2	0	0·5
	50	50·0

$P = \cdot 76$.

Mean Population 92, Standard Deviation 68·96, Coefficient of Variation 74·81.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XIX.

ROHTAK VILLAGES 200—300.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of epidemics	Observed number	Expected number
0	21	18·53
1	13	18·22
2	7	3·98
3	0	0·27
4	0	0·00
	41	41·00

$P = \cdot 36$.

Mean Population 257, Standard Deviation 27·81, Coefficient of Variation 10·83.

TABLE XX.

ROHTAK VILLAGES BETWEEN 300 AND 400.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of epidemics	Actual number	Expected number
0	24	22·44
1	16	20·47
2	8	4·75
3	0	0·34
4	0	0·05
	48	48·05

$P = \cdot 30$.

Mean Population 352, Standard Deviation 30·34, Coefficient of variation 8·62.

TABLE XXI.

ROHTAK VILLAGES 500—700.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of epidemics	Observed number	Expected number
0	19	14·33
1	20	28·69
2	20	16·69
3	3	2·27
4	0	0·03
	62	62·01

$P = \cdot 28$.

Mean Population 603, Standard Deviation 57·08, Coefficient of Variation 9·46.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXII.

ROHTAK VILLAGES 700—900.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of epidemics	Observed number	Expected number
0	9	7·40
1	17	19·76
2	15	14·29
3	2	1·56
	43	43·01

$P = \cdot 82$.

Mean Population 784·23, Standard Deviation 57·36, Coefficient of Variation 7·31.

TABLE XXIII.

ROHTAK VILLAGES 950—1200.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of epidemics	Observed number		Expected number	
0	9		5·35	
1	20		25·67	
2	27		24·69	
3	1	3	3·21	3·29
4	2		0·08	
	59		59·0	

$P = \cdot 26$.

Mean Population 1059, Standard Deviation 87·18, Coefficient of Variation 8·24.

TABLE XXIV.

ROHTAK VILLAGES POPULATION 1400—1700.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of epidemics	Actual number	Expected number
0	3	2·0
1	11	14·12
2	27	23·89
3	3	3·86
4	0	0·13
	44	44·00

$P = \cdot 75$.

Mean Population 1465, Standard Deviation 130·92, Coefficient of Variation 8·94.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXV.

ROHTAK 2000—2950.

Comparison of numbers actually affected in various epidemics with expected numbers.

Number of epidemics	Actual number	Expected number
0	2	0·80
1	6	8·78
2	25	23·40
3	6	5·67
4	0	0·36
	39	39·01

$P = \cdot 53$.

Mean Population 2373, Standard Deviation 230·89, Coefficient of Variation 9·73.

TABLE XXVI.

Relation between Goodness of Fit and Variation in Size.

No. in Group	Average Population	Coefficient of Variation	*P*
	ROHTAK.		
*50	92	68·96	·76
41	257	10·83	·36
48	352	8·62	·30
62	603	9·46	·28
43	784	7·31	·82
59	1059	8·24	·26
44	1465	8·94	·75
39	2373	9·73	·53
	MOZUFFARNAGAR.		
164	404	14·54	·48
141	606	10·65	·11
139	917	10·98	·000
82	1247	7·73	·03
72	1746	10·81	·28
*89	4137	76·05	·006
	AMRITSAR.		
45	175	7·97	·156
53	276	5·13	·035
160	308	20·41	·001
*390	708	25·13	·000
153	1257	13·75	·000
*129	3837	366·61	·07

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXVII.

Showing the influence of the non-infected villages on the Goodness of Fit.

No. of villages in the group	Percentage of total number in the group which should not be infected	Actual difference between calculated and observed number	Percentage contribution of this difference to the value of χ^2	Fit
		ROHTAK.		
39	2·05	+ 1·2	56·80	·53
62	23·01	+ 4·68	30·02	·28
48	46·71	+ 1·56	2·93	·30
43	17·21	+ 1·60	38·74	·82
41	45·19	+ 2·47	7·53	·36
44	4·55	+ 1·0	26·10	·75
59	9·07	+ 3·65	62·50	·26
50	81·00	− ·5	1·00	·76
		MOZUFFARNAGAR.		
82	3·68	+ 4·98	74·99	·03
139	10·88	+14·88	54·71	·00
72	3·04	+ 2·91	57·63	·28
164	31·02	+ 6·13	29·36	·48
141	19·94	+ 7·89	24·93	·11
89	1·06	+ 3·06	61·58	·01
		AMRITSAR.		
153	3·07	+ 9·3	64·76	·00
390	3·05	+17·1	46·73	·00
53	15·09	+ 5·0	30·14	·04
45	26·27	+ 5·18	33·94	·16
160	14·78	+11·35	29·15	·00

TABLE XXVIII.

To show the influence of Size and Grouping on the Goodness of Fit (P).

Values of P which result when the groups are reduced to a total of 44 villages in each case and only 5 classes are used.

ROHTAK.		AMRITSAR.		MOZUFFARNAGAR.	
Group	Goodness of Fit (P)	Group	Goodness of Fit (P)	Group	Goodness of Fit (P)
200—300	·32	150—200	·16	500—750	·60
300—400	·34	250—300	·07	750—1100	·08
500—700	·46	200—400	·28	1100—1400	·21
1400—1700	·75	400—1000	·24	1400—2200	·44
2000—2950	·47	1050—1600	·15	Greater than 2000	·10
		Greater than 1600	·57		
Mean	·47	Mean	·25	Mean	·29*

* Two Rohtak and one Mozuffarnagar Groups contain four classes only, reduced to a total of 44, they give :

R. 700—900 ·82 R. 950—1200 ·40 M. 350—500 ·87

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

TABLE XXIX.

Amritsar villages tested for recurrences in successive years of plague.

1. GROUPS USED.

Population limits	No. of villages in the group
1200—1400	46
1000—1200	67
800—1000	97
500—700	166
400—500	97

2. RESULTS ARRANGED IN GROUPS.

	1903 and 1904		1904 and 1905		1905 and 1906		1906 and 1907	
Group	No. affected in both years	Expected no. affected in both years	No. affected in both years	Expected no. affected in both years	No. affected in both years	Expected no. affected in both years	No. affected in both years	Expected no. affected in both years
1200—1400	25	23·65	27	27·83	17	14·78	10	12·93
1000—1200	26	25·03	33	30·85	25	24·52	23	22·21
800—1000	32	28·93	41	39·36	31	26·53	28	23·42
500—700	39	30·27	45	42·38	20	17·71	20	12·99
400—500	16	14·65	15	16·44	16	15·88	13	14·14
Goodness of Fit (P)	**·54**		**·91**		**·84**		**·25**	

3. TOTALS ARRANGED IN YEARS.

Years	No. affected in both years	Expected no. affected in both years	
1903—4	138	122·53	
1904—5	161	156·86	
1905—6	109	99·42	$P=$**·29**
1906—7	94	85·69	

TABLE XXX.

Percentages of villages affected in any one year which did not report cases in the previous year.

Population limits	Infected in 1904 but not 1903 (percentage of all villages infected in 1904)	1905 but not 1904	1906 but not 1905	1907 but not 1906
1200—1400	18·8	32·5	0	71·4
1000—1200	30·8	37·7	9·7	52·1
800—1000	30·4	49·4	3·1	60·6
500—700	41·8	57·1	28·6	74·0
400—500	41·4	72·7	35·7	73·5

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

PART III. GENERAL SUMMARY OF CONCLUSIONS.

(1) While there is an appreciable number of villages in which the interval elapsing between the last death in one epidemic and the first death in the next following epidemic is so short that it is unnecessary to postulate a re-introduction of the disease, in the great majority the interval of freedom is so long that a re-importation of the infective agent is more likely to be the cause of the outbreak than recrudescence.

(2) The villages in which the infection has been, or may have been, carried over from one epidemic to the next are generally of large size and, with the exception of certain large towns, vary from year to year.

(3) A study of the later plague history of villages infected in the milder epidemics and of villages infected at the ends of epidemics confirms the conclusions stated in (1).

(4) A study of the distribution of infected villages in maps showing the position of affairs month by month suggests a spreading out of the infection from various centres, although, when the infection becomes widespread, this may be difficult to trace.

(5) Paying no attention to the respective sizes of the different villages, the numbers attacked in none, one, two, etc. epidemics do not form a random, or chance, distribution.

(6) There is a direct relation between the number of epidemics in which villages have been attacked and the average population of such villages. The average population of villages which have never been attacked is very small.

(7) The chief factor in the non-random distribution mentioned in (5) has been the great variation in size of village within each district. In Amritsar some other factor has also been very influential, in Mozuffarnagar and Rohtak no agency other than discrepancies in size can be definitely shown to exist.

(8) The incidence of plague in the Amritsar district is unlike that found in the other two districts.

(9) The statistical evidence does not point to the conclusion that the fact of a village having been infected in any one epidemic renders it more liable to be infected in the next following epidemic.

(10) Certain villages appear to possess an immunity distinct from the relative immunity conferred by low average population.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

XXXVI AND XXXVII. OBSERVATIONS ON PLAGUE IN BELGAUM AND POONA.

IN a former number of these reports (*Journal of Hygiene*, vol. VIII. p. 266) in an article dealing with the "Seasonal Prevalence of Plague in India," an endeavour was made to reconcile the facts of seasonal prevalence with the view that the transmission of the plague bacillus from rat to rat and from rat to man was effected through the agency of the rat flea. We demonstrated that plague could not exist, in epidemic form, in any of the six places that we selected for study, when the mean daily temperature was as high as 85° F. When this temperature is reached plague epidemics receive a check and rapidly decline. While this was so we pointed out that epidemics could and occasionally did decline and come to an end at times when the temperature appeared to be most suitable. It was clear that in such instances other factors come into play. In no places was this fact so well demonstrated as in Belgaum and Poona. It was for these reasons that we selected these two towns as the most suitable for further observations. We hoped to be able to throw some light on these other factors, and their relative importance. Climatic conditions appeared to be favourable to plague all the year round in Belgaum and for the greater part of the year in Poona.

It will be convenient here to recapitulate the propositions with which we closed the above quoted communication. We therein stated, "The rise of the rat epizootic and in consequence of the human epidemic depends upon:

(*a*) A suitable mean temperature somewhat below 85° F. and in general over 50° F.

(*b*) A sufficient number of susceptible rats.

(*c*) A sufficient number of rat fleas.

The fall of the rat epizootic and in consequence the epidemic, is determined by some or all of the following factors:

(*a*) A high mean temperature, 85° F. and above.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press

(*b*) A diminution in the total number of rats and an increase in the proportion of immune to susceptible animals.

(*c*) A diminution in the number of rat fleas."

How far these propositions hold good in the case of Poona and Belgaum, where the factor of a high mean temperature can be excluded, will become apparent from a perusal of the following pages. The Commission takes the opportunity of tendering their thanks to G. Carmichael, Esquire, I.C.S., Collector of Poona, and B. A. Brendon, Esquire, I.C.S., Collector of Belgaum, for their cordial assistance freely rendered at all times. The thanks of the Commission are also due to the Municipalities of Poona, Belgaum and Shahapur and the Cantonment authorities of Poona and Belgaum for their cooperation and interest in the work carried out in the districts under their control.

https://doi.org/10.1017/S0022172400043023 Published online by Cambridge University Press