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In an attempt to more closely relate the size of primary schools in Uttar Pradesh, India to the teaching activities, an experiment was conducted in some forty schools where classrooms were provided only for lessons for which covered space was essential. All other lessons were conducted in the open on the school site. An area utilization reduction of about 40% was achieved as well as a side effect of greater student interest due to increased individual activity. Climatic conditions in India were examined and it was concluded that outdoor teaching north of latitude 19 degrees North and below 2,000 feet above mean sea level is quite feasible. (NI)

ASIAN REGIONAL INSTITUTE FOR SCHOOL BUILDING RESEARCH

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COLOMBO

1967

Occasional Paper - School Building N° 13

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A Method of Reducing Classroom Requirements in Primary Schools in Asia

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PREFACE

In most Asian countries there is a need to stretch the annual budget for primary school buildings to its limit so that the maximum number of new places is constructed annually. In such a context the educationist faces the alternatives of providing more conventional building solutions for fewer children, or devising other and perhaps less orthodox ways of getting more children into school without lowering the quality of education provided.

There are many ways of tackling this problem: more places can be provided by reducing the gross covered area per student, by lowering the cost of construction, by arranging for the building to be used in shifts and so on.

It was with these problems in mind that in 1964 the Asian Regional Institute for School Building Research produced a paper entitled "A Comparative Study of Multi-Purpose Rooms in Educational Buildings". 1/ In this a method was introduced for accurately measuring the utilisation of space in schools by means of a use-factor. The method involved comparison of the optimum use of each unit area of covered space for every hour of the day, with the actual use per hour. The resulting ratio gave the use-factor.

Examination of schools in the Asian Region showed use-factors as low as 25% to be quite common.

In a country such as India the application of these ideas is of special relevance for although the overall enrolment in Indian primary schools is high, the number of children yet to be housed is such as to require very heavy capital investment in building. Moreover, first-level education which in India is a State responsibility has developed at different rates from state to state. 2/ Some states thus face a much more formidable primary school building programme than might be thought to be the case from a study of the overall situation.

1/ Asian Regional Institute for School Building Research. Occasional papers; school building, no.7: A comparative study of multi-purpose rooms in educational buildings. Bangkok, Unesco, 1964.

2/ MISRA, ATMANAND. Educational balance-sheet of States. Education quarterly v.17, no.66 (Jun) 1965, p.64-8, 83. New Delhi, Ministry of Education, Government of India.

In 1966, Mr.R.D.Srivastava, architect at the Central Building Research Institute, Roorkee, India, started further work on use-efficiency with a view to achieving economy of space in Indian schools. He decided, as a result of this, to establish ways of making more sensible use of space in primary schools. Working with Dr.B.M.Gupta, District Inspector of Schools for Saharanpur (U.P.), India, an experiment was started, the object of which was to achieve maximum use of covered space through the provision of classrooms only for teaching those subjects which could not be taught outside on the school site.

The result of this work was to increase the use-factor to 85% and to reduce the gross covered area of the standard primary school by 40%.

Clearly, the approach to the problem involves much more than a mere reduction of the area of the building. The feasibility of the solution will depend not only on maintenance of the quality of education but also on the existence of suitable climatic conditions for outdoor teaching.

The Asian Regional Institute, whilst publishing the papers of Mr.Srivastava and Dr.Gupta, has provided an analysis of rainfall and a tentative study of thermal comfort conditions in India which will, it is hoped, serve to highlight the climate and the very considerable advantages in terms of capital investment and education where the weather is clement.

It has also suggested fields of possible further study in relation to points arising from the two papers.

This paper outlines an approach through a study of the curriculum and the corresponding need for covered space. The conclusions reached may be thought unreasonable by those used to more conventional school buildings, but in the context in which they apply, they undoubtedly present a solution to the problem of getting into school children who would otherwise have no opportunity of primary education.

CONTENTS

LIST OF ILLUSTRATIONS

SUMMARY

In at attempt more closely to relate the size of primary schools in Uttar Pradesh, India, to the teaching activities, an experiment was conducted in which in some forty schools, classrooms were provided only for lessons for which covered space was essential. All other lessons were conducted in the open on the school ...

The results showed that not only can a reduction of 40% be achieved in the area needed for a primary school building, but that the use of the site as well as the building for lessons resulted in greater student interest as well as improved standards of instruction.

Outdoor teaching depends upon clement weather. Climatic conditions in India were therefore examined and it was concluded that outdoor teaching is quite feasible in India north of a latitude of 19°N and below an altitude of about 2,000 ft. above mean sea-level.

Further study of long-range effects of this experiment would be of considerable advantage in view of its significance to school building in India. Architecturally, long-range weather observations are necessary to check conclusions on thermal comfort and further work could be done on establishment of a thermal comfort index for the people of North India. Educationally, further study over a period of one or two years is needed on the effects on teaching and teachers, and learning and pupils, of the proposals for changes in time-table, and non-provision of base-rooms for all classes.

SOMMAIRE

Afin d'établir une relation plus étroite entre les dimensions des écoles primaires à Uttar Pradesh (Inde) et les activités de l'enseignement, on tenta une expérience par laquelle, dans quarante écoles, des salles de classe furent fournies seulement pour les leçons qui exigeaient un espace couvert. Toutes les autres classes eurent lieu, à ciel ouvert, sur les terrains de l'école.

Les résultats prouvent qu'il est non seulement possible de réduire de 40% l'espace nécessaire à l'enseignement dans une école primaire, et que l'emploi du terrain en même temps que l'emploi de l'école elle-même eut comme résultat une augmentation de l'intérêt apporté à leurs études par les étudiants ainsi qu'une amélioration du niveau d'enseignement.

L'enseignement à ciel ouvert dépend de la clémence du temps. Les conditions climatériques en Inde furent donc examinées et on arriva à la conclusion que l'enseignement en plein air est très possible en Inde au nord d'une latitude de 19° et au-dessous d'une altitude d'environ 2,000 pieds, au-dessus du niveau de la mer.

Une étude plus approfondie des conséquences les plus réculées de ces expériences serait d'un avantage considérable étant donné l'importance qu'elle présente pour la construction d'écoles en Inde. Du point de vue architectural, des observations prolongées du temps sont nécessaires dans le but d'obtenir des conclusions sur le confort thermal, et des travaux plus approfondis pourraient mener à l' établissement d'une liste alphabétique sur la question de confort thermal à l'intention des habitants du nord de l'Inde. Du point de vue de l'enseignement, des études plus prolongées pendant une période d'un ou deux ans seraient nécessaires pour se rendre compte de l'effet produit sur l'enseignement et sur les professeurs, et d'autre part, sur les études des élèves et sur les etudiants eux-mêmes, ainsi que des propositions de changements des programmes, et le fait qu'il n'existera pas d'espaces couverts pour toutes les classes.

CHAPTER - 1

ARCHITECTURAL APPROACH TO INCREASED USE OF SCHOOL SITE AND BUILDINGS

1.1 INTRODUCTION

In India there is a continuing and increasing demand for new school places and better teaching facilities from the very limited funds available. Millions of school-going children are required to be housed in school buildings to meet the national target of compulsory primary schooling. This naturally requires a very large number of school buildings. It is, therefore, necessary that every possible saving be achieved in the architectural, physical and structural design of new schools.

One way of ensuring that no unused spaces are included in future designs of schools is to use existing spaces to the maximum. In designing new schools all other things being equal, reductions in the areas provided will result in reductions in cost. In India very little information is available regarding costs and design standards for various types of school building.

A study on use-efficiency of school spaces was therefore made, aimed at finding out how economies in spaces could be effected through continuous use during the school day of space in school buildings and on school sites.

1.2 USE-EFFICIENCY

In most of the schools in India, verandahs are provided for the sole purpose of circulation. There are other rooms which are never used full-time. This leads to increases in cost. To determine the extent of use of spaces it was necessary to study the teaching time-table in relation to the plan of the building.

From this study it was possible to express the actual use of each space in relation to the length of the school day during which the building was in use. The use-efficiency percentage is defined as the ratio between the actual and ideal use per sq.ft. per hour, as follows:

$$\text{Use-Efficiency\%} = \frac{\text{Area of space actually used} \times \text{Time used} \times 100}{\text{Total area of space available} \times \text{Total time school open}}$$

A typical school building plan of five classrooms (see Fig.1) was related to the time-table being followed in local primary schools and a sample formula is worked out on the following pages.

The time-table in terms of outdoor and indoor periods is indicated below:-

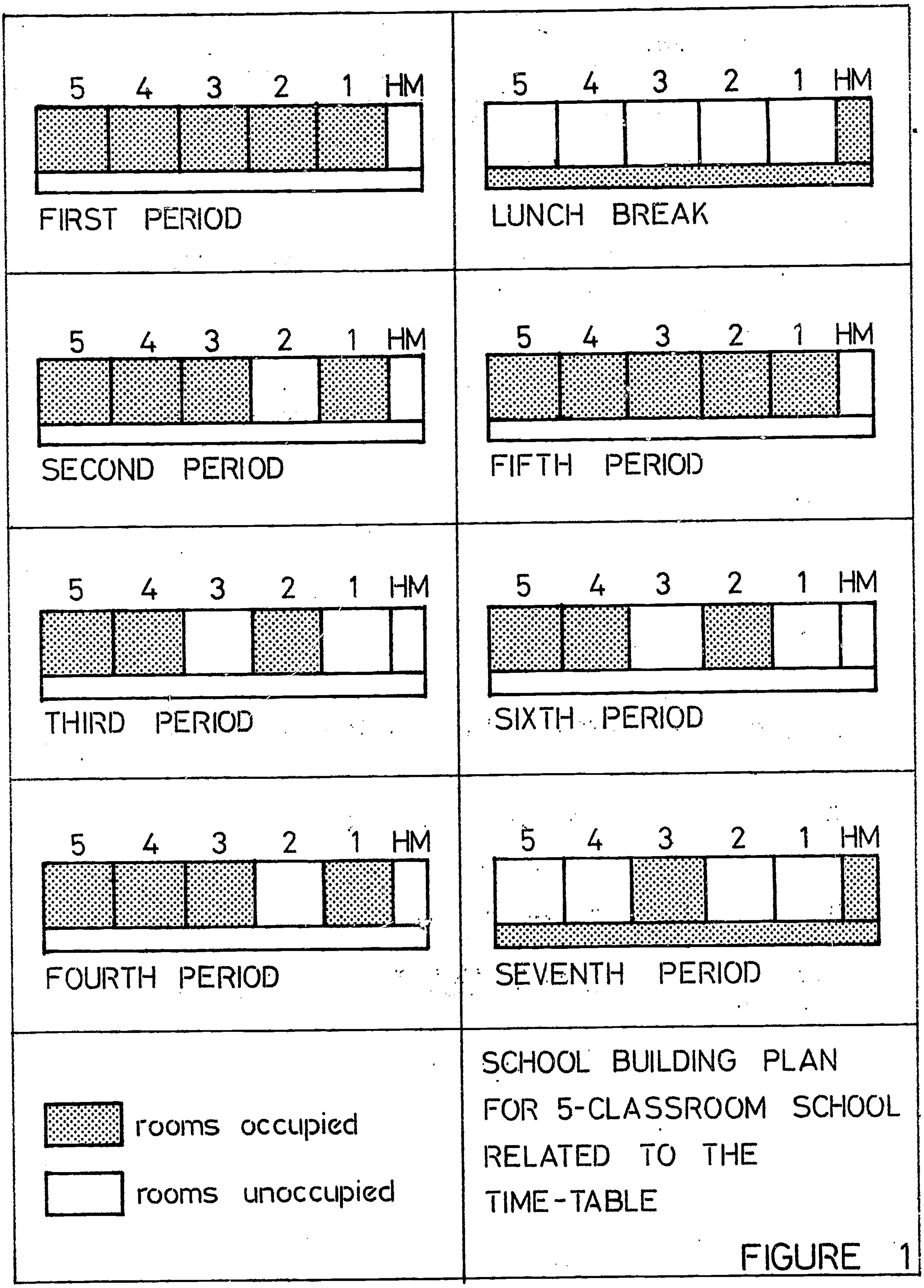
PERIODS:		1st	2nd	3rd	4th		5th	6th	7th
TIME	10 a.m. 10.10	10.10 10.55	10.55 11.40	11.40 12.25	12.25 1.10	1.10 1.50	1.50 2.30	2.30 3.10	3.10 3.50
CLASS V	PRAYERS	Hindi	G.Sci & Agri.	Maths	(OUT) Games & P.T.	LUNCH * BREAK	Eng-lish	(OUT) Craft	Social Study
IV		Hindi	(OUT) Craft	Eng-lish	(OUT) Games & P.T.		Maths	Social Study	Gen. Sci.
III		Social Study	(OUT) Craft	Hindi	Maths		(OUT) Games & P.T.	Eng-lish	Gen. Sci.
II		(OUT) Craft	Maths	(OUT) Games & P.T.	Hindi		Social Study	Count-ing & tables	-
I		(OUT) Craft	Hindi	(OUT) Social Study	Hindi writ-ing		(OUT) Games & P.T.	Maths	-

TABLE 1 - PROPOSED EXPERIMENTAL TIME-TABLE FOR A 5-CLASS PRIMARY SCHOOL

Notes:

School day: 16th April - 31 August : 7 a.m. to 12 noon
1st September - 15th April: 10 a.m. to 4 p.m.

Long Vacation: 1st to 30th June



SCHOOL BUILDING PLAN FOR 5-CLASSROOM SCHOOL RELATED TO THE TIME-TABLE

FIGURE 1

The $5\frac{1}{4}$-hour teaching day (10 a.m. - 3.15 p.m.) with eight periods of forty minutes (including lunch-period) was the general pattern. The study revealed that the use-efficiency percentage of the school building was 53% and that of the verandah and master's room was as low as 25%. The use-efficiency percentage of classrooms ranged from 52% to 76% as is indicated in Table 2 below:

TABLE 2 - CALCULATION OF USE-EFFICIENCY PERCENTAGE OF THE SCHOOL

Teaching Periods:

Class	Inside Periods	Outside Periods (Including Lunch-break)
I	4	4
II	4	4
III	5	3
IV	6	2
V	6	2

The use-efficiency percentage of a classroom was calculated as follows:

Classroom Area = 7.31m x 6.1m = $44.55m^2$

Period Actually Used = 2.7 hours

Total Time School Open = 5.25 hours

$$\text{Use-efficiency\%} = \frac{\text{Area of classroom} \times \text{Time used} \times 100}{\text{Area of classroom} \times \text{Total time school open}}$$

$$= \frac{44.55 \times 2.7 \times 100}{44.55 \times 5.25}$$

$$= 51.6\%$$

TABLE 2 - CALCULATION OF USE-EFFICIENCY PERCENTAGE, continued

This calculation was repeated for every space in the building with the following results:

Class I	=	52%
Class II	=	52%
Class III	=	63%
Class IV	=	76%
Class V	=	76%
Verandah	=	25%
H.M.Room	=	25%

The use-efficiency of the building as a whole was calculated as follows:

$$\text{Use-efficiency \%} = \frac{\sum(\text{Area of spaces actually used} \times \text{Time used}) \times 100}{\text{Total area of building} \times \text{Total time school opens}}$$

(Area of spaces used x Time used) is given by:

Class I :	$44.55m^2 \times 4 \times \frac{40}{60}$ hrs	$= 118.8m^2$hrs
Class II :	$44.55m^2 \times 4 \times \frac{40}{60}$ hrs	$= 118.8m^2$hrs
Class III :	$44.55m^2 \times 5 \times \frac{40}{60}$ hrs	$= 148.5m^2$hrs
Class IV :	$44.55m^2 \times 6 \times \frac{40}{60}$ hrs	$= 178.2m^2$hrs
Class V :	$44.55m^2 \times 6 \times \frac{40}{60}$ hrs	$= 178.2m^2$hrs
Verandah :	$60.22m^2 \times \frac{(6 \times 5) + 40}{60}$	$= 70.2m^2$hrs
H.M.Room :	$18.60m^2 \times \frac{80}{60}$	$= 24.8m^2$hrs
$\sum$(Area used x Time used)		$= 837.5m^2$hrs

Use-efficiency % for whole school $= \frac{837.5 \times 100}{301.57 \times 5.25} = 53\%$

1.3 INCREASED USE-EFFICIENCY

To achieve economy in buildings, increased use-efficiency was attained by eliminating the less used spaces and by establishing rational relationships between teaching periods in the school plan.

By eliminating the verandah and the headmaster's room, the use-efficiency of the school building increased to 63% and a reduction of 25% in space was obtained. These spaces may be desirable features of schools but since their elimination does not strictly affect education they may be left out until more funds for construction are available.

In an effort to achieve optimum use of classroom space, the time-table was analysed and re-arranged. The rational application of the time-table to the school building plan (see Fig.2) indicated that a five-class primary school could very well function with three classrooms only.

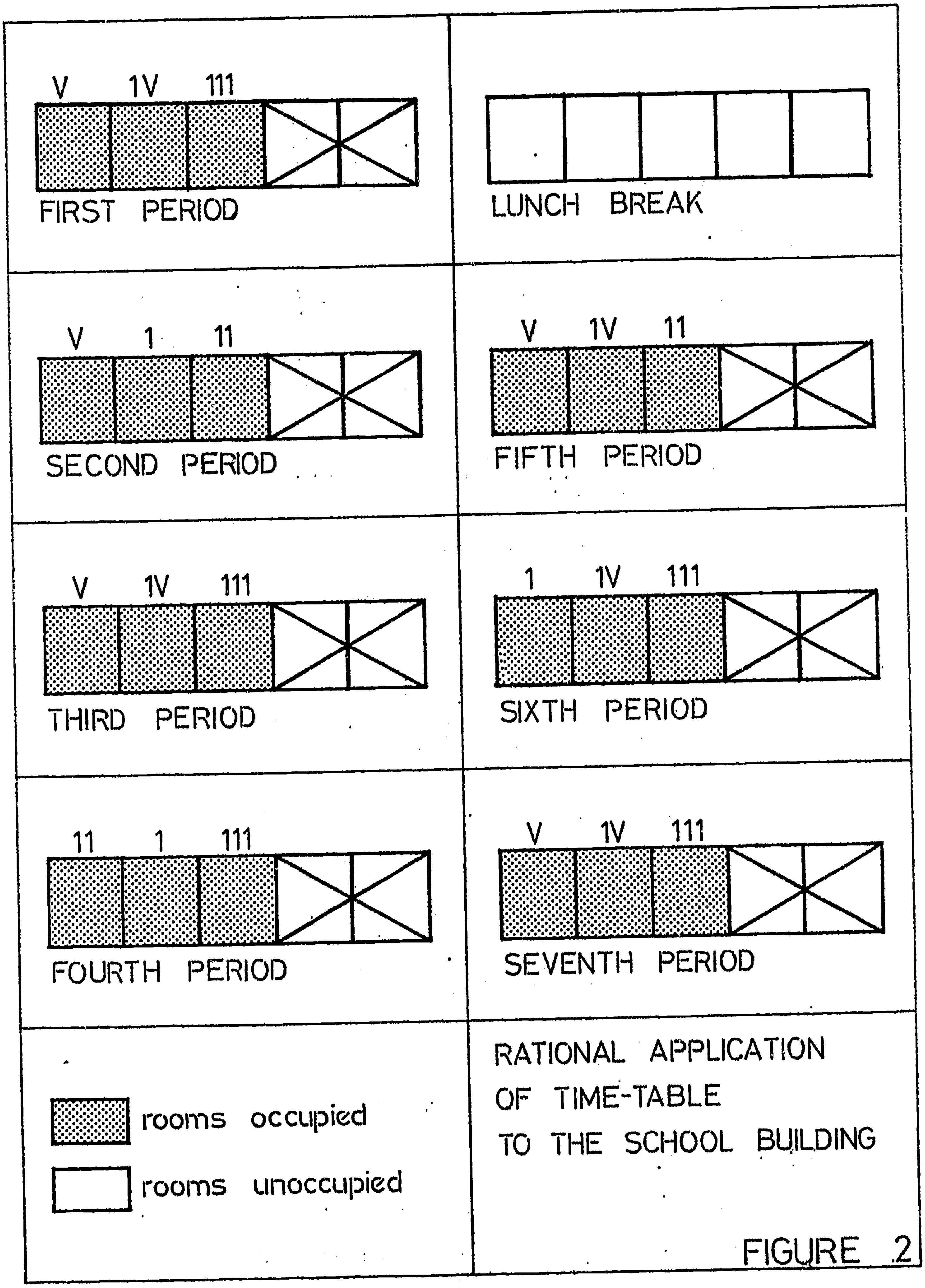
This increased the use-efficiency to 89% and effected a reduction of 40% in the overall teaching space requirements, as is indicated here in Table 3.

TABLE 3. REVISED USE-EFFICIENCY PERCENTAGE OF SCHOOL

Teaching Periods:

Class	Inside Periods	Outside Periods (Including Lunch-break)
I	3	4
II	3	4
III	5	3
IV	5	3
V	5	3

Use-efficiency % for whole school = $\frac{623.7}{133.77} \times \frac{100}{5.25}$ = 89%



RATIONAL APPLICATION OF TIME-TABLE TO THE SCHOOL BUILDING

FIGURE 2

1.4 ACTUAL TRIALS IN SCHOOLS

Before any final conclusions could be drawn from the above study it was considered necessary to examine the implications through actual observation. This was done in forty schools in and around Roorkee, all having the basic education curriculum. The experiments were conducted on both rainy and clear days.

1.5 EXPERIMENTS ON RAINY DAYS

Since outdoor teaching during rainy periods was not possible, it became necessary to accommodate all students inside the building. It was decided under such conditions to combine in one room Classes I and II and in another, Classes III and IV, while Class V was allotted the third room.

In the combined classes it was found that separate time-tables for each class were not workable. It was then decided to adjust the time-tables so that one class took Writing, while the other took Reading. This improved the situation a little. Next, a time-table was tried in which combined classes were taught the same subject. This enabled the combined class to run smoothly with less strain on the teacher. The use-efficiency of the spaces was found to be 89%.

1.6 EXPERIMENTS ON NORMAL DAYS

In this experiment an effort was made to achieve 100% use-efficiency of spaces during the school day by staggering the mid-day lunch break, but this did not find favour with the teachers.

The time-table was again revised in the following way:

a) the mid-day lunch break was the same for all classes;

b) three classes were to be inside the building and the two classes outside were to take the same subjects at the same time, e.g. gardening, physical training, craftwork or games;

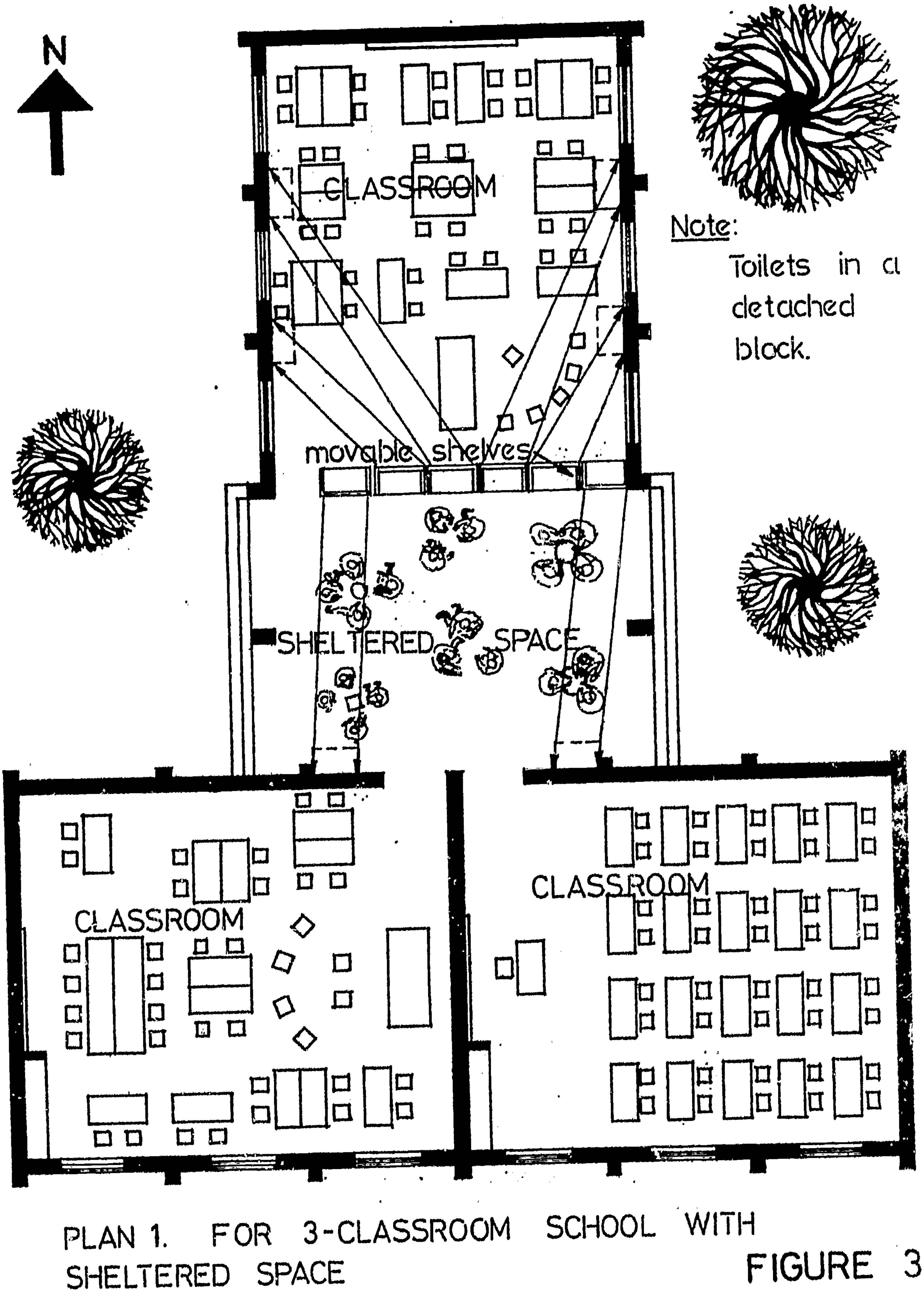
c) movement of classes was to be kept to a minimum;

d) no space was to remain unused.

1.7 OBSERVATIONS

The following points were noted during the experiment:

a) Space was required for the bastas (satchels) of students changing classes.



PLAN 1. FOR 3-CLASSROOM SCHOOL WITH SHELTERED SPACE

FIGURE 3

b) During bright sunlight, outdoor lessons were uncomfortable.

c) On an average, 5 minutes were wasted each time classes moved from room to room.

A solution to problems (a) and (b) above could be found by providing some device for keeping bastas outside on numbered tat-patti (mats) and by providing some sheltered spaces for outdoor activities during rainy or hot weather.

1.8 FINDINGS

i. Three classrooms with a sheltered space instead of five classrooms are adequate for a school of five classes.

ii. Optimum use of spaces is attained with 89% use-efficiency.

iii. Students learn more through activity programmes, which though included in the curriculum are often not realised.

The study also indicated that if school buildings are to be economically and spatially efficient, they should not be designed by architects alone: educationists must collaborate from the outset by indicating the use-efficiency of every space and where possible dovetailing the time-table with the plan of the building.

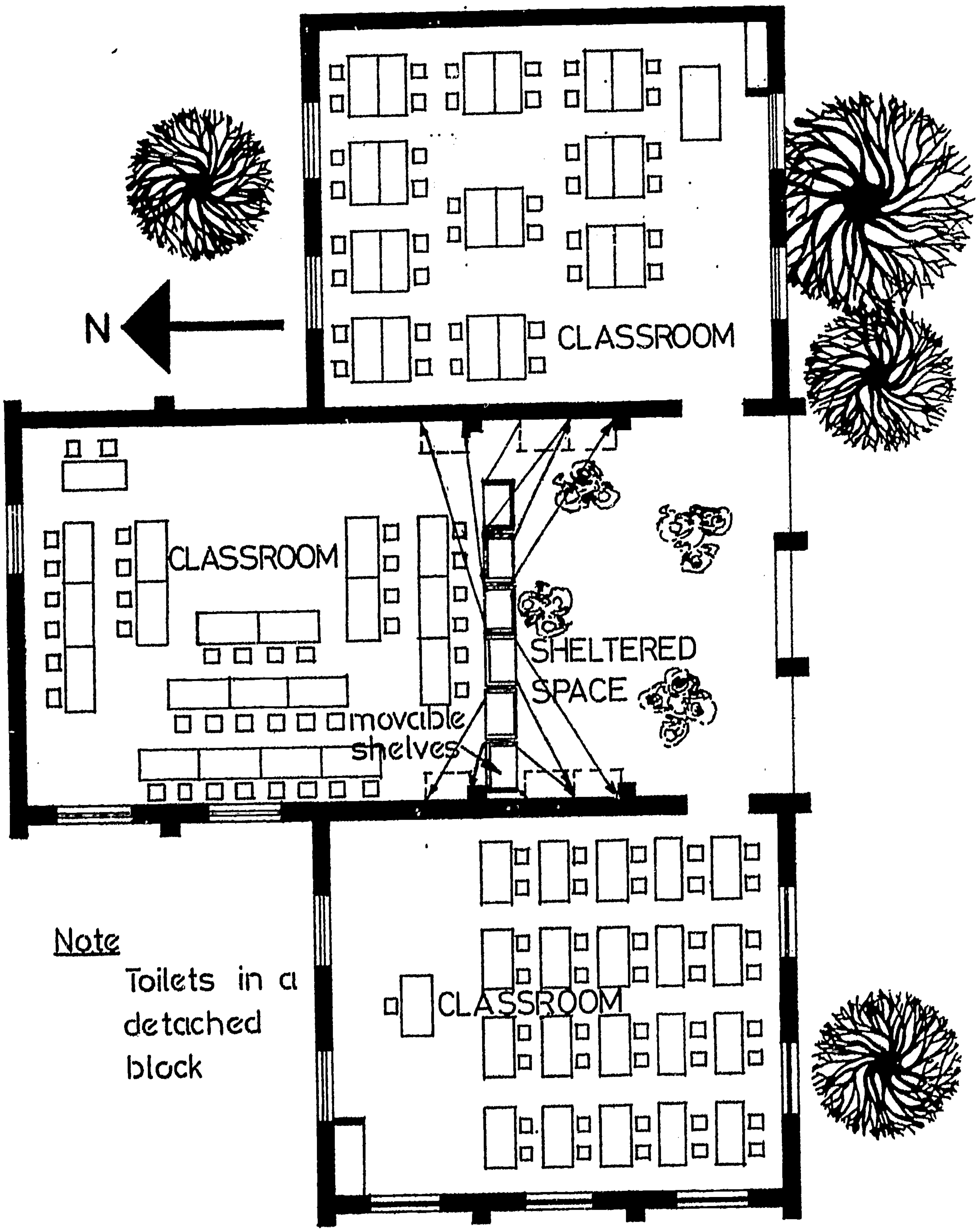
1.9 SCHOOL PLANS

As a result of these findings and to cater for climatic requirements, two alternative school plans have been developed, one for a composite climate where summer and winter are both comparatively more severe and the other for humid wet climates.

Plan 1 (Fig.3)

The use-efficiency experiments indicated the need for a sheltered space in addition to three classrooms. The sheltered space is to be used for craft work, clay work, spinning and weaving, etc. on normal days; in addition, on days of inclement weather this space can be used for the class which would normally be in the garden for P.T. or gardening, and which could join the class doing craft in the sheltered space.

This space is located at a point where in combination with the middle classroom, it can serve as a large area for combined activity. In winter



PLAN 2. FOR 3-CLASSROOM SCHOOL WITH SHELTERED SPACE

FIGURE 4

with cold wind, or summer with hot wind, a temporary partition or removable shelves can be arranged on the open side to check undesirable wind.

Plan 2 (Fig.4)

The sheltered space will serve as teaching space when it rains. Since all the doors of the classrooms open onto it, the need for a verandah is eliminated. Adequate cross-ventilation has also been provided in this plan.

CHAPTER - 2

EFFECT OF CLASSROOM REDUCTION ON EDUCATION

2.1 GENERAL

The supervisory staff of the Education Department of Saharanpur district (U.P.), India, became interested in the research project conducted by C.B.R.I., Roorkee, because of the possibility it envisages of economies in school buildings through increased use-efficiency of available spaces in primary schools. The economy study was arranged by closing two classrooms in a five-class school and examining its use as a school with only three rooms. It was, of course, required that the standard of instruction should not suffer on account of the reduced covered teaching space provided.

The study was ultimately extended to about forty schools in the Saharanpur district teaching the basic curriculum. During the first stage of the experiment, an effort was made to identify the subjects which could most easily be taught in open spaces using normal instructional practices. These subjects included physical culture with games for lower classes; basic crafts such as clay work; gardening; art and local crafts etc. The teaching of multiplication tables to lower classes through clay balls, sticks and other activity methods is also easily taught in open or in sheltered spaces.

With the present pattern of instruction, Classes I and II are required to attend school from 10 a.m. until 4 p.m. This is a long and strenuous period for a child of six or seven years of age. In the new time-table, these classes will terminate at 3.20 p.m.

2.2 THE TEACHING TIME-TABLE

Having identified the subjects which could be taught in the open, and after studying carefully the educational specifications, a time-table (see Table 1) was evolved to suit the new spatial provision. The time-table was such, that three classes were in the building and two either outside or in sheltered space, depending upon the subjects being taught. As the experiment proceeded, the following problems were faced by the teachers:-

1. The students had to move in and out of the classrooms with their heavy bastas (satchels) hung on their shoulders. If they left them in the classrooms such difficulties occurred as the loss of notebooks, pencils and slates.

To solve this problem, the provision of shelves or pegs was recommended. An economical solution was found by providing matting (tat-pattis) outside in the open, marked with numbers where students could keep their bastas. This worked fairly well.

ii. Outdoor lessons for activity and creative work necessitate regular physical movement from building to site and site to building, and it was observed by the majority of the teachers that students were refreshed and invigorated by this change of teaching location. However the time lost in change of classes (about five minutes) and the risk of indiscipline made certain teachers unhappy. To minimise this lost time, it was suggested that every room, cost permitting, should be provided with two doors, to be used respectively as exit and entrance. In the absence of extra doors, students can be guided to move in single file. This requires teachers to be more alert and conscientious of the need to maintain discipline. When this systematic movement was practised, room-changes were performed in two minutes.

iii. A great responsibility was laid on the teachers to plan their lessons so as to finish within the prescribed time. The movement from site to building and building to site, and the resultant improved planning of the lessons by the teacher raised both the quality of instruction and pupil interest and achievement.

2.3 THE WEATHER

A difficulty which could not be entirely surmounted, was the inclemency of the weather. During inclement weather, all five classes had to be housed in three classrooms and a sheltered space. Two classes had to be combined, keeping in view their tuitional standards. The combination of Classes I and II was troublesome because of the larger number of children in these classes compared with the more senior classes, and also because being less mature than the older classes they were less amenable to organisation. On the other hand, combinations of Classes IV and V, or III and IV, worked tolerably well.

The normal time-table was suspended during these inclement days, and work of a type likely to sustain the interest of combined classes was planned. For example, in language periods, recitation and composition could be easily taught; in arithmetic periods, recapitulation of multiplication tables and mental arithmetic proceeded satisfactorily. In the social studies period, narration of simple stories and recapitulatory questions did well. Such adjustments were poor compensation for the normal teaching work, but since the number of inclement days are quite small and the economy in capital expenditure on construction of school buildings was very considerable, the system could be recommended.

2.4 FINDINGS

At the end of the experiment, an opinion survey was conducted amongst the teachers and field staff, and the general consensus of opinion was:-

i. The standard of instruction had improved.

ii. Students took more interest in their lessons.

CHAPTER - 3

CLIMATIC FEASIBILITY OF OUTDOOR TEACHING

3.1 GENERAL

In the preceding chapters an architect and an educationist of Uttar Pradesh, India examined the possibility of teaching a part of the primary school curriculum in the open on the school site. The architect concludes that, if this is educationally feasible, the standard five-classroom primary school building can be reduced by almost 40% in area. The educationist concludes, after a period of experiment in some forty schools, that use of the site, as well as the building, for teaching results in greater student interest and improved standards of instruction.

From this it would seem that, first, substantial per place savings in capital investment can be achieved, allowing more new places to be built; and second, that dropouts may be reduced through the improvement in quality of education.

In examining these studies the main doubt that must be expressed is the feasibility of regular outdoor teaching in relation to rainfall and thermal comfort. The Asian Regional Institute for School Building Research therefore decided to examine the patterns of rainfall in India and tentatively to establish thermal comfort indices so that those interested in applying the results of the studies would be able to evaluate the probable success of indoor/outdoor teaching in relation to climatic situations other than that experienced in Uttar Pradesh.

3.2 RAINFALL 3/

An examination of the mean number of rainy days for the following twenty-eight Indian cities shows two distinct patterns of distribution:

ABU	BANGALORE	JODHPUR	NEW DELHI
AGRA	BARODA	KANPUR	PATNA
AHMEDABAD	BIJAIPUR	LUCKNOW	POONA
ALIGARH	COIMBATORE	LUDHIANA	ROORKEE
ALLAHABAD	INDORE	MADRAS	TIRUCHIRAPALLI
AMBALA	JAIPUR	MADURAI	VARANASI
AURANGABAD	JHANSI	MYSORE	VISAKHAPATNAM

3/ Data provided by C.B.R.I., Roorkee.

See Graphs 1-8 at end of this paper.


LUDHIANA
AMBALA
ROORKEE
NEW DELHI
ALIGARH
LUCKNOW
PATNA
AGRA
KANPUR
VARANASI
ALLAHABAD
JHANSI
JAIPUR
JODHPUR
ABU
INDORE
AHMEDABAD
BARODA
VISAKHAPATNAM
AURANGABAD
SECUNDERABAD
POONA
BIJAIPUR
MADRAS
BANGLORE
MYSORE
COIMBATORE
TIRUCHIRAPALLI
PONDICHERRY
MADURAI
19°N
incidence of rainy days too great for outdoor teaching

FIGURE 5

In the southern part of the sub-continent from May to November there are generally more than five rainy days per month and from July to October the number increases to over eight.

In sharp contrast to this, in central and northern India, from June to September there may be between 10 and 16 rainy days a month whilst, for the rest of the year there are only one or two days on which rain fall. Graphs in the appendices illustrate the pattern of rainy days in India. Some of this rain will fall at night and some on days when schools are not open. Schools are also on holiday in June or July when the frequency of rainy days is greatest.

It may be concluded from this brief examination; that where rain falls on more than five or six days a month, the probable interruptions to the teaching programme occasioned by crushing the students from outside into inside spaces not designed to contain them, would be intolerable.

Thus for India, roughly south of latitude 19°N (Fig 5) the concepts outlined in the preceding chapters would probably not be valid as far as building design is concerned, although the value of outdoor teaching is clearly demonstrated.

3.3 THERMAL COMFORT

a) General

Thermal comfort is subjective. Whilst complete agreement may be obtained on what is thermally uncomfortable, it is unlikely that more than 60% or 70% of a group of people will agree that any particular situation is thermally comfortable.

A further difficulty occurs in connection with the establishment of criteria for thermal comfort. Webb 1/ has developed an index of comfort for a population of acclimatised subjects in Singapore. The comfort index, which is for an ordinary indoor climate where radiation is limited, is based on dry and wet bulb temperatures and air movement. Thermal comfort occurs between an index of 75°F and 85°F and the majority of the people will be comfortable at an index of 78°F.

1/ Webb's comfort index may be found in various articles and papers such as: Indian construction journal, 1961 (Dec) and 1962 (Jan) 23-32: Thermal comfort and discomfort; a review by C.G.Webb.

The use of the index for acclimatised Indian children sitting under shade trees is problematical. However in the absence of the other suitable means of assessing thermal comfort, it was thought the index might form a useful if rough guide. The study that follows is thus of comfort indices in certain Indian states using Webb's criteria, applied to outdoor shaded situations. The answers obtained will not be as dependable as if all of Webb's criteria for measurement had been observed, but they will be of the right order. In studies of this sort a reasonable approximation is the most for which we can hope, in the light of present knowledge and of the highly subjective nature of thermal comfort. An informed guess is better than no guess at all!

There is, however, a need to extend Srivastava's and Gupta's studies into the field of thermal comfort. It is hoped that, using the method adopted by Webb, a better idea can eventually be obtained of the reaction of children to the varying thermal situations that they experience working outside in shade. One of the main problems to be resolved in this connection is the maximum comfortable wind speed that can be tolerated.

In much of the north of India as well as in countries such as Iran and Afghanistan where winter temperatures are very low, it is already customary for the children, who are often very lightly clothed, to go outside for lessons in the winter months, taking advantage of the early morning sun. Thus we already know that thermal comfort can be achieved outside the building. The problem that remains is to establish the optimum conditions for thermal comfort in outdoor shaded situations in the various parts of India and in other countries as well.

b) Estimation of Thermal Comfort Indices

Climatic data provided by the C.B.R.I., Roorkee, indicated monthly mean dry bulb temperatures, relatively humidity, and wind-speeds. In the case of Roorkee, for example, the data were re-arranged as follows:-

TABLE 4 - CLIMATIC DATA FOR ROORKEE, INDIA

MONTH	Mean D.B. Temp. °F	Mean W.B. Temp. °F	Wind-Speed ft./sec.	Mean Daily Max. °F
Jan.	46.4	44	158	68.4
Feb.	50.8	48	194	72.5
Mar.	61.3	54	220	83.8
Apr.	74.5	60	246	95.7
May	83.9	67	282	102.2
June	85.1	74	282	100.2
July	81.9	77	220	92.1
Aug.	80.7	77	176	89.7
Sept.	77.9	73	150	90.5
Oct.	68.2	63	106	82.2
Nov.	55.4	51	88	79.6
Dec.	73.3	70	114	71.2

D.B. = Dry Bulb
W.B. = Wet Bulb

During the month of June, schools in Uttar Pradesh are closed for vacation. Data for this month can thus be discarded. From April to August when mean daily maximum temperatures are high, schools are open during the mornings only from 7 a.m. to 12 noon. The mean dry bulb temperature can thus safely be used for estimating comfort indices during these months. For the rest of the year schools are in attendance from 10 a.m. to 4 p.m. and the mean daily maximum can be more realistically used. Data re-arranged in this way will then be as follows:-

TABLE 5 - RE-ARRANGED CLIMATIC DATA FOR ROORKEE, INDIA.

MONTH	D.B.Temp. °F	W.B.Temp. °F	Wind-Speed ft/sec	School Attendance
Jan.	68.4	44	158	10 a.m. - 4 p.m.
Feb.	72.5	48	194	" "
Mar.	83.8	54	220	" "
Apr.	95.7	78	246	7 a.m. - 12 noon
May	83.9	67	282	" "
June	S C H	O O L	V A	C A T I O N
July	81.9	77	220	7 a.m. - 12 noon
Aug.	80.7	77	176	" "
Sept.	90.5	73	150	10 a.m. - 4 p.m.
Oct.	82.2	63	106	" "
Nov.	79.6	51	88	" "
Dec.	71.2	70	114	" "

D.B. = Dry Bulb
W.B. = Wet Bulb

Using the Webb nomogram, the equatorial comfort indices for each month are as follows:-

TABLE 6 - THERMAL COMFORT INDICES FOR ROORKEE, INDIA

MONTH	Equatorial Comfort Index °F	Notes
Jan.	less than 70°F	uncomfortably cold
Feb.	" " "	" "
Mar.	" " "	" "
Apr.	78°F	comfortable
May	72°F	cold
June	S C H O O L	V A C A T I O N
July	75.25°F	comfortable
Aug.	70.50°F	cold
Sept.	77.75°F	comfortable
Oct.	70°F	cold
Nov.	less than 70°F	uncomfortably cold
Dec.	" " "	" "

This data supports in a dramatic way the statement made by Srivastava in Chapter 1 above: "Considering various factors such as inadequate clothing of children, outdoor teaching in the sun during these months (October to February) is more comfortable".

The other 18 cities [5] north of the 19°N latitude for which climate data is available, fall into two groups as follows:-

1. Wind-Speeds <u>less</u> than 300 ft/sec. for most of the year	2. Wind-Speeds <u>more</u> than 300 ft/sec. for most of the year	
Ambala	Abu	Bijaipur
Jhansi	Agra	Indore
Lucknow	Ahmedabad	Jaipur
Ludhiana	Aligarh	Jodhpur
New Delhi	Allahabad	Kanpur
Varanasi (Benares)	Aurangabad	Patna
	Baroda	

In those cities with wind-speeds greater than 300 ft/sec. it will be assumed that wind breaks can be provided to reduce the wind-speed to less than 300 ft/sec. and on this assumption the two groups have been examined for thermal comfort.

The full analysis is give in Table 7. From this it is clear that during the winter months, thermal discomfort is likely to be experienced even inside buildings and outside teaching in the sun may prove thermally more satisfactory. The reason for teaching in the mornings only during May, July and August are implicit in the data and it is also clear that the later start and longer day in the winter months is to obtain benefit from the heat which occurs later in the day.

5/ Spelling of the names of the cities mentioned above and elsewhere in this paper are taken from The Times Atlas of the World. Mid-century edition. v.2. London; Times Publishing co., 1959.

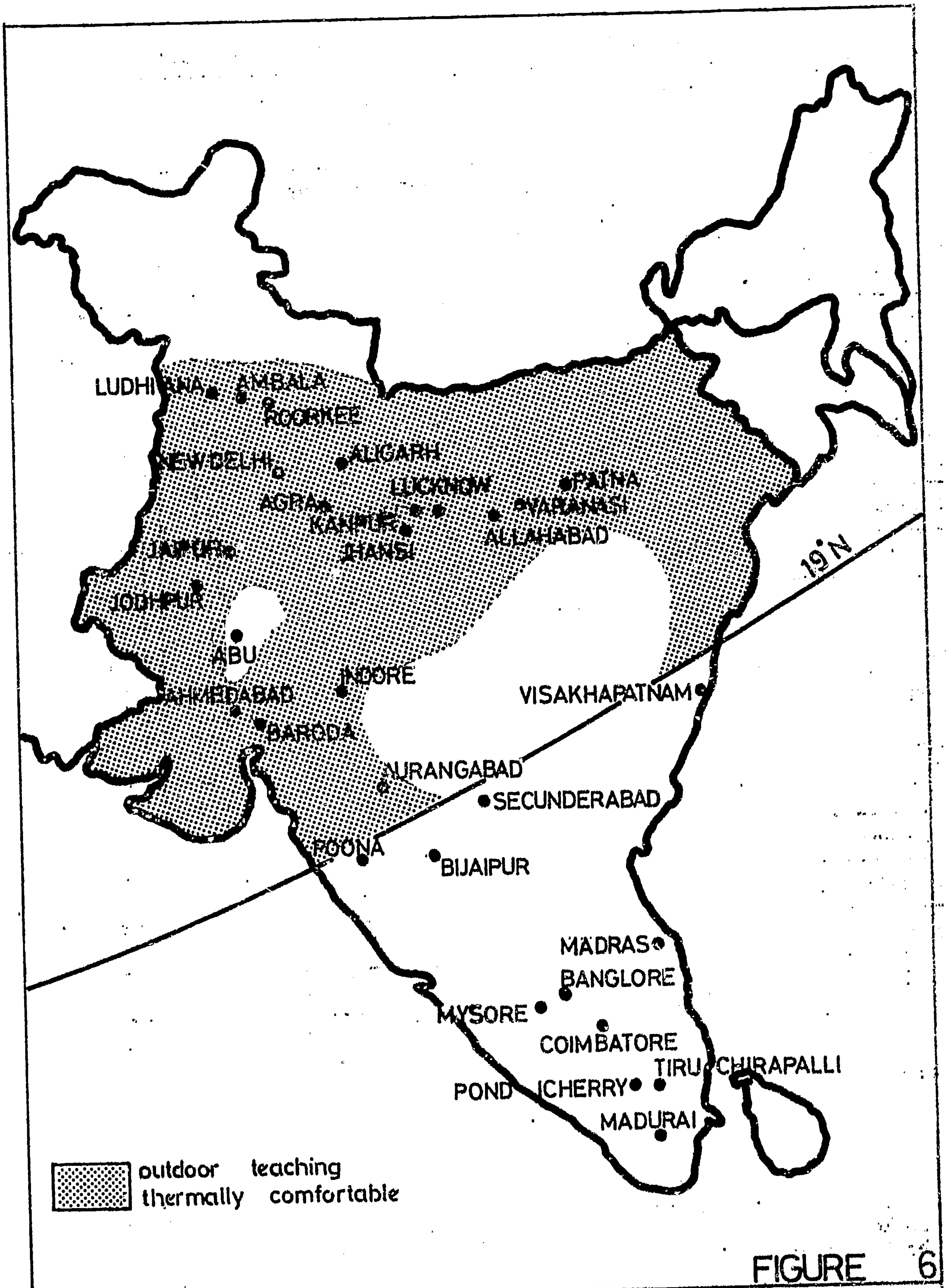

LUDHIANA
AMBALA
ROORKEE
NEW DELHI
ALIGARH
LUCKNOW
PATNA
VARANASI
AGRA
KANPUR
ALLAHABAD
JHANSI
JAIPUR
JODHPUR
ABU
INDORE
AHMEDABAD
BARODA
VISAKHAPATNAM
AURANGABAD
SECUNDERABAD
19°N
POONA
BIJAIPUR
MADRAS
BANGLORE
MYSORE
COIMBATORE
TIRUCHIRAPALLI
PONDICHERRY
MADURAI
outdoor teaching thermally comfortable

FIGURE 6

TABLE 7 - MEAN EQUATORIAL COMFORT INDEX °F. (Note: *70°= less than 70°)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ht. above Mean S.L. ft.
Abu	*70°	*70°	*70°	*70°	*70°	S	*70°	*70°	*70°	*70°	*70°	*70°	3,945
Agra	*70°	70°	76°	78°	74°	C	76°	75°	82°	78°	75°	70°	553
Ahmedabad	*74°	76°	82°	82°	75°	H	75°	74°	83°	82°	77°	75°	163
Aligarh	*70°	*70°	75°	77°	73°	O	75°	75°	81°	80°	74°	*70°	615
Allahabad	*70°	71°	77°	79°	75°	O	76°	75°	81°	79°	76°	70°	322
Ambala	*70°	70°	75°	77°	72°	L	76°	76°	83°	78°	74°	*70°	892
Aurangabad	*75°	75°	77°	78°	73°		*70°	*70°	77°	76°	75°	74°	1,905
Baroda	*75°	77°	79°	82°	75°		75°	74°	82°	85°	80°	77°	115
Indore	*70°	72°	76°	78°	74°		*70°	*70°	78°	77°	75°	73°	1,823
Jaipur	*70°	*70°	75°	77°	74°		75°	73°	81°	78°	74°	*70°	1,431
Jhansi	*70°	72°	76°	79°	76°	V	75°	75°	75°	79°	75°	*70°	824
Jodhpur	*70°	70°	75°	78°	73°	A	75°	73°	83°	79°	75°	*70°	736
Kanpur	*70°	70°	75°	78°	75°	C	76°	76°	82°	79°	76°	*70°	413
Lucknow	*70°	73°	77°	79°	76°	A	77°	76°	84°	81°	*70°	*70°	371
Ludhiana	*70°	*70°	75°	80°	73°	T	77°	77°	85°	81°	74°	*70°	812
New Delhi	*70°	*70°	75°	78°	73°	I	73°	75°	82°	78°	73°	*70°	714
Patna	*70°	70°	76°	80°	76°	O	76°	76°	81°	79°	75°	*70°	173
Roorkee	*70°	*70°	*70°	78°	72°	N	75°	70°	78°	70°	*70°	*70°	899
Varanasi (Benares)	*70°	71°	80°	80°	78°		77°	75°	82°	80°	76°	*70°	250

An index of 85°F = uncomfortably hot
75°F = uncomfortably cold
78°F = comfortable

S.L. = Sea Level

In areas about 1000 ft. above mean sea-level and higher, outdoor teaching will probably be difficult due to the wind. For example, at Abu, 3,945 ft. above mean sea-level winds are so strong and temperatures so low, that any outside activity not involving exercise, will probably be impossible.

Fig.6 shows the area in which proposals for outdoor teaching are feasible, from the point of view of thermal comfort.

CHAPTER - 4

FURTHER STUDIES

4.1 GENERAL

This paper reports on an hypothesis and limited experiments relating to a topic which is of great significance in bringing education to more children. An expanded programme of construction is made possible through savings achieved in the reduction of space in schools. A project of such importance is worthy of further study to assess the long range effects resulting from its implementation. These studies will naturally fall into two divisions:-

a) Architectural studies;
b) Educational studies.

4.2 FURTHER ARCHITECTURAL STUDIES

The north of India has a dry climate and this forms the basis for the entire experiment. The climate is typified also by very high dry bulb temperatures in the months from March to October and by very low temperatures in the mornings from November to February. The experiment in the forty schools near Roorkee is of about one year's duration. There is a need to extend the observations for a year or two in order to check beyond all doubt the conclusions reached on thermal comfort. The high wind speeds in some areas can only be offset through the use of wind-breaks. Can these breaks be constructed easily? Is the dust which is common in parts of northern India a nuisance?

Secondly, and arising from the question of thermal comfort, there is the question of the establishment of a thermal comfort index for the people of north India. What combination of wet and dry bulb temperatures and of wind speed do they find most comfortable? Is the use of the Singapore Comfort Index valid for populations other than acclimatised Singaporeans?

4.3 FURTHER EDUCATIONAL STUDIES

As can be seen from paragraph 2.2.1 above, greater responsibility is placed on teachers in planning lessons where movement of classes from place to place at precise times is planned. The proposals in this Paper present a greater challenge to the ingenuity and organisational ability of the teacher than the earlier method of continuous teaching in one classroom for the whole of the school day.

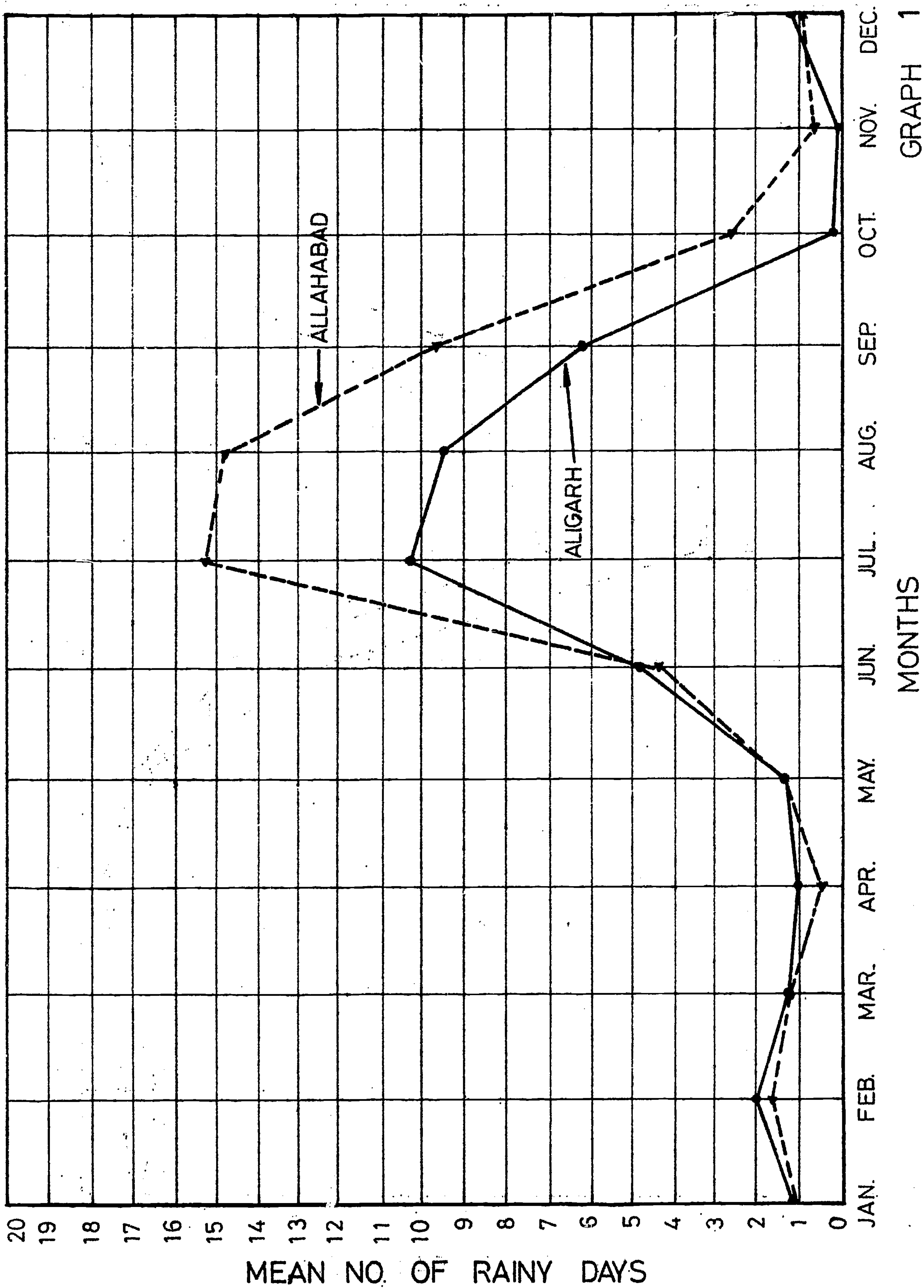
Certainly, bearing in mind the novelty of the experiment and the urgency of the school building problem, it would be of interest to observe over a much longer period the effects of rigid time-tabling on their learning activities and their usual behaviour. It is important to assess the effect, if any, upon primary school classes of not having a "base-room".

4.4 BUILDINGS AND EDUCATION

One of the great gaps in knowledge in the school building field, is that of the relationship between school buildings and educational quality. We have no objective evidence on classroom shapes, little conclusive research on the influence of class size on learning; the importance of building shape to efficient teaching and learning is not known;[6] there are no categorical answers to the question of whether to build horizontally or vertically and there is even substantial disagreement on the amount of light needed in teaching spaces.

The experiment reported in this paper is of especial value as it is concerned with a topic about which we, at present know very little - "the need for shelter in connection with learning". Long ago in India the "guru" taught successfully under a tree. At present the tree is replaced by buildings. Somewhere between the two might, as the Paper suggests, be a happy solution.

6/ Mc Clurkin, W.D. School building planning. New York, Macmillan, 1965.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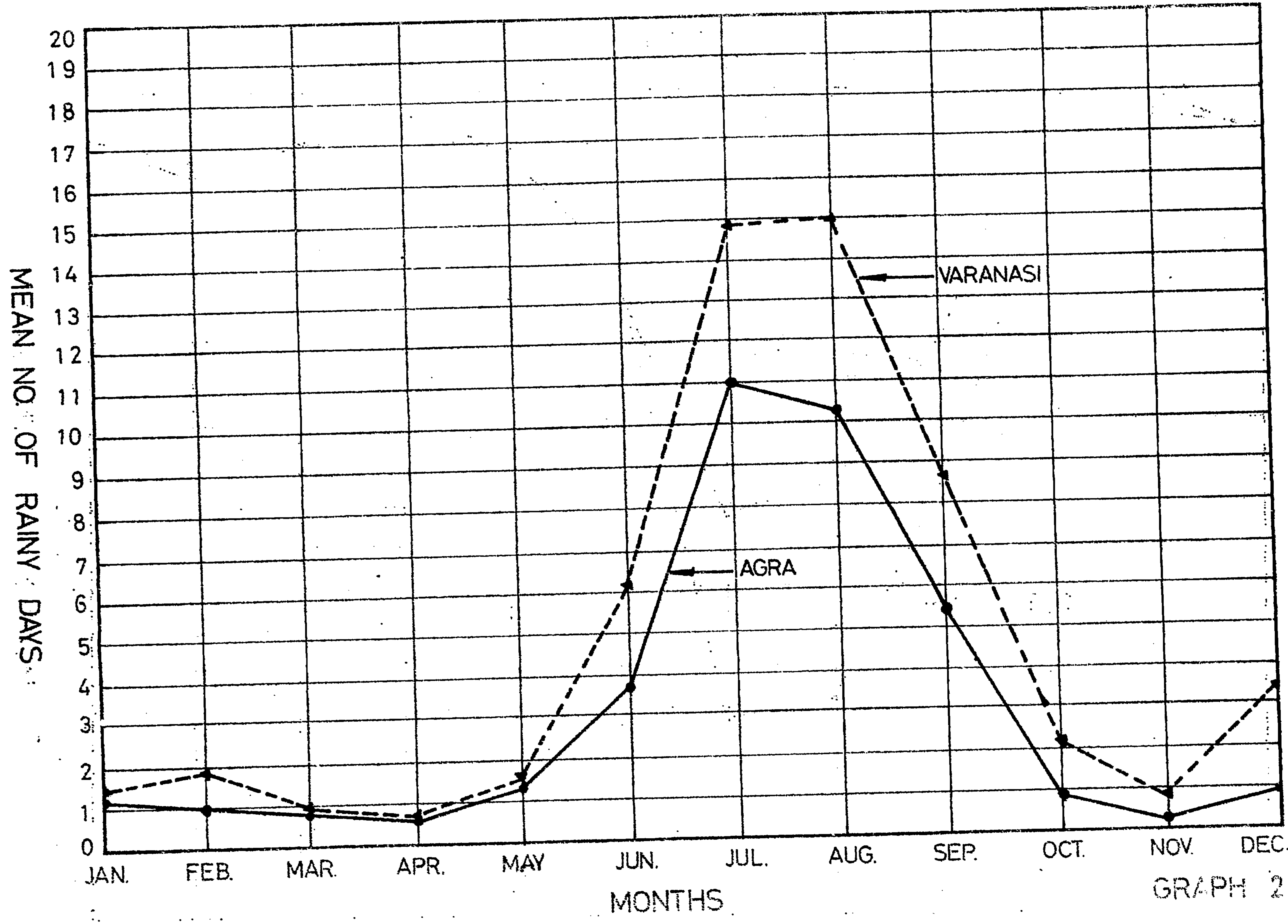
MEAN NO. OF RAINY DAYS

GRAPH 1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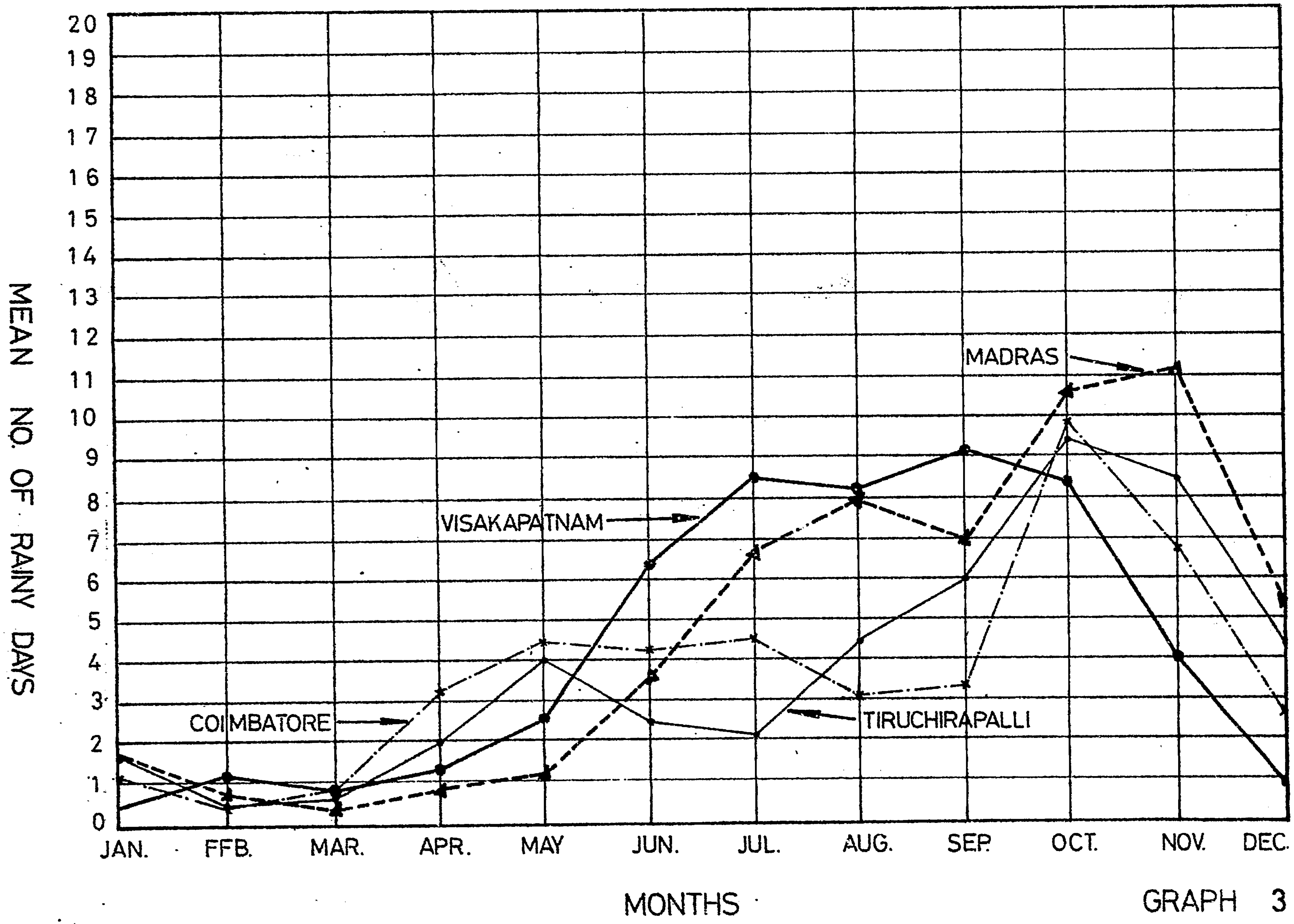
GRAPH 2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COIMBATORE
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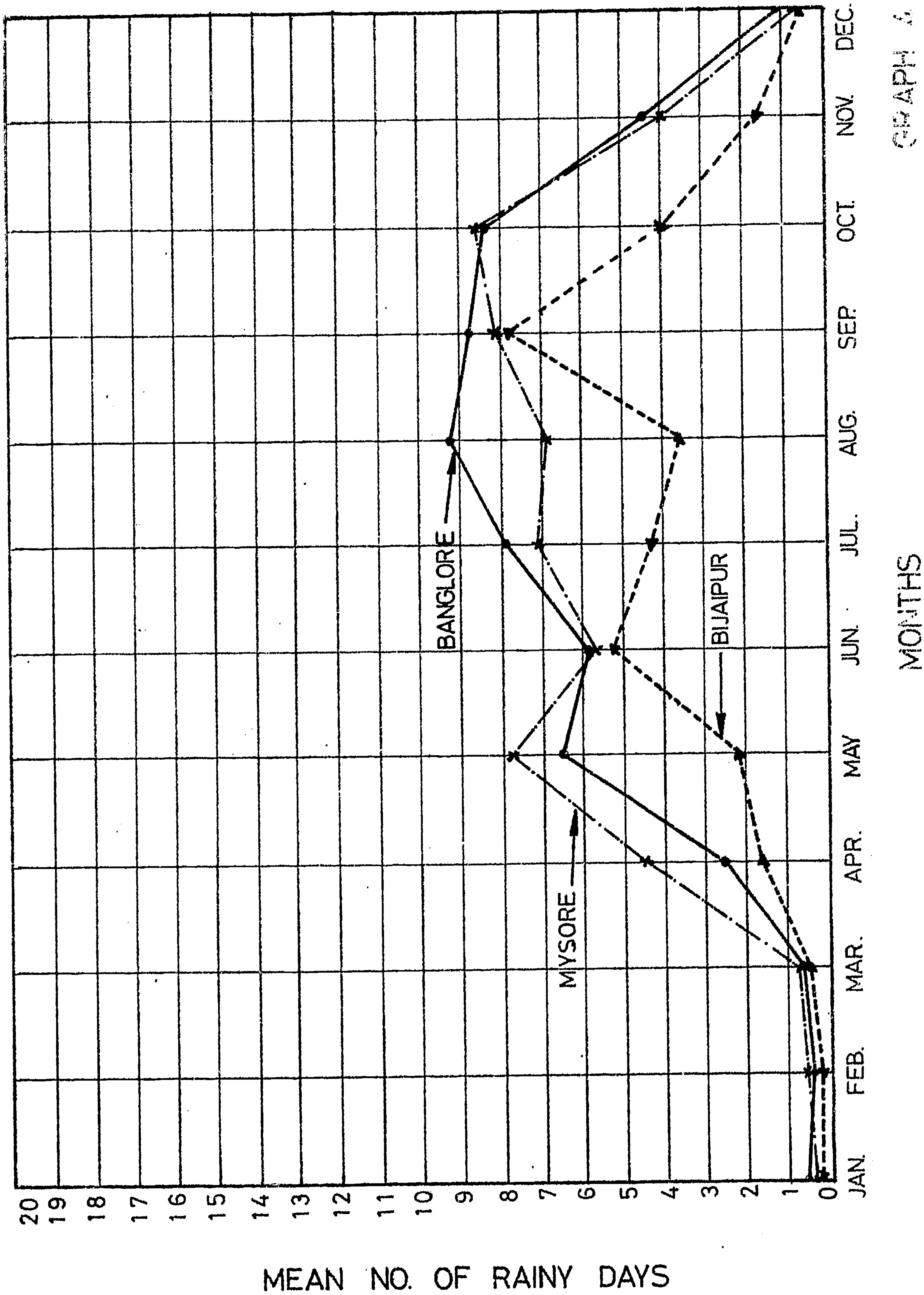
MONTHS

GRAPH 3



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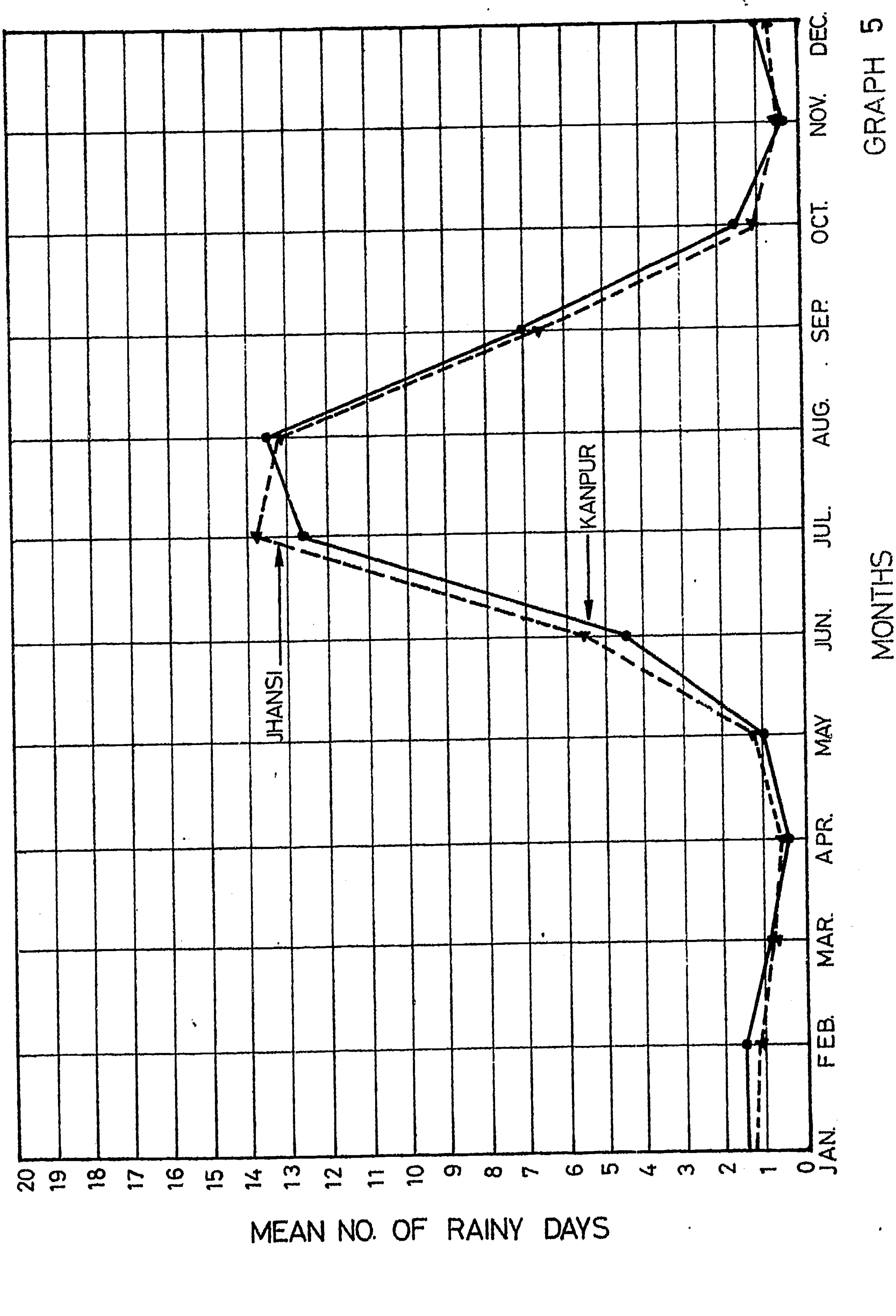
MEAN NO. OF RAINY DAYS

GRAPH 4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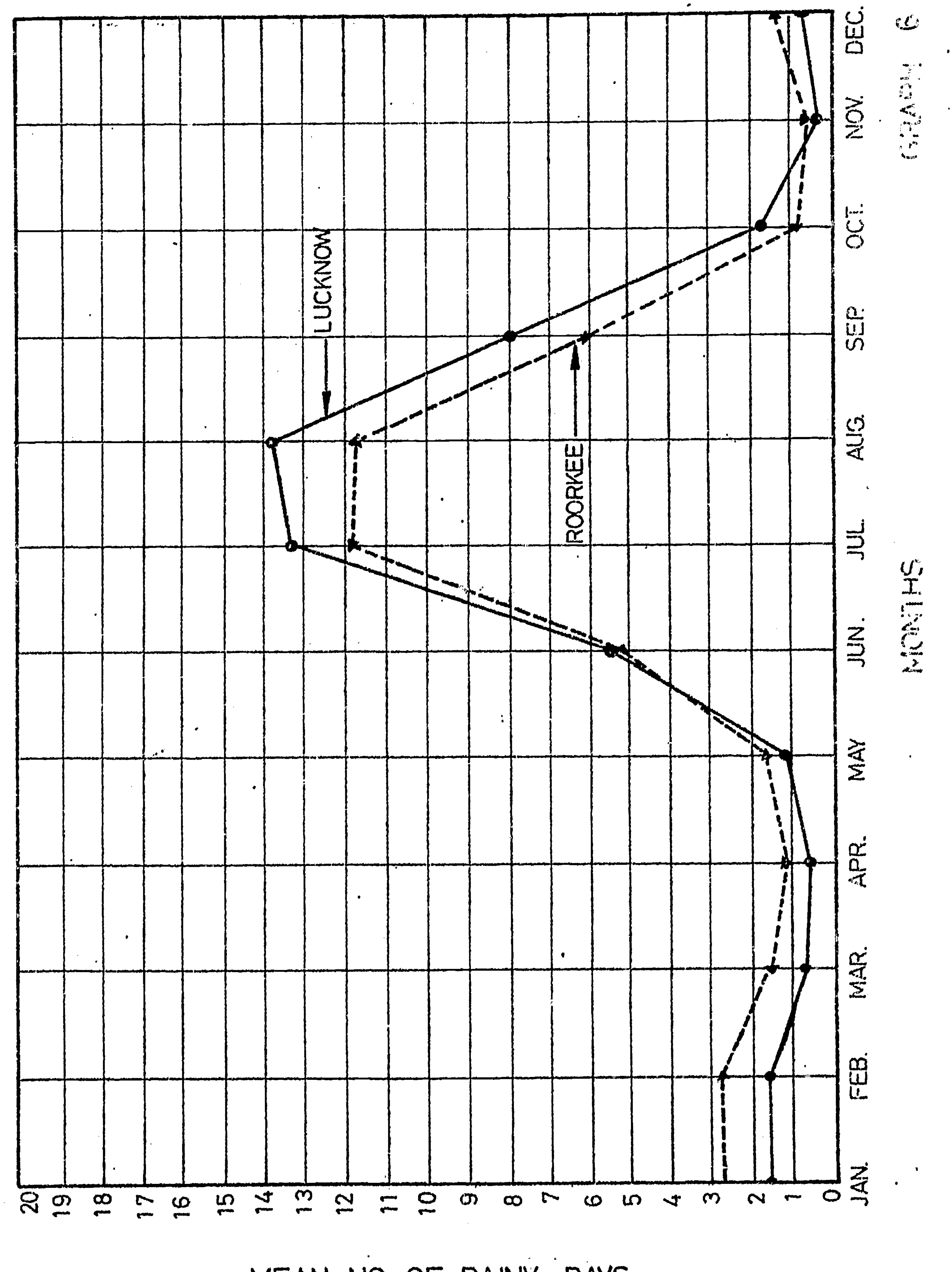
GRAPH 5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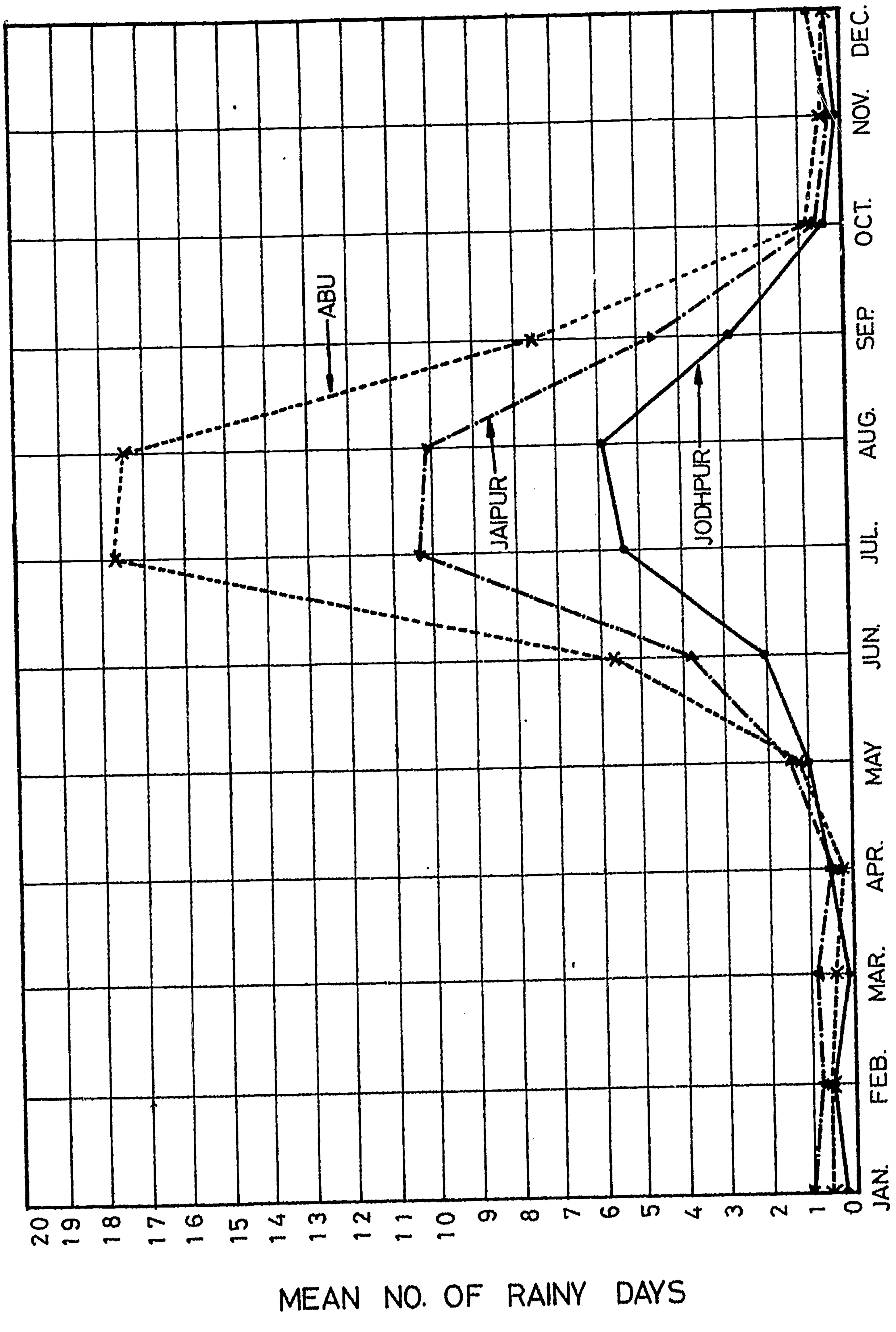
GRAPH 6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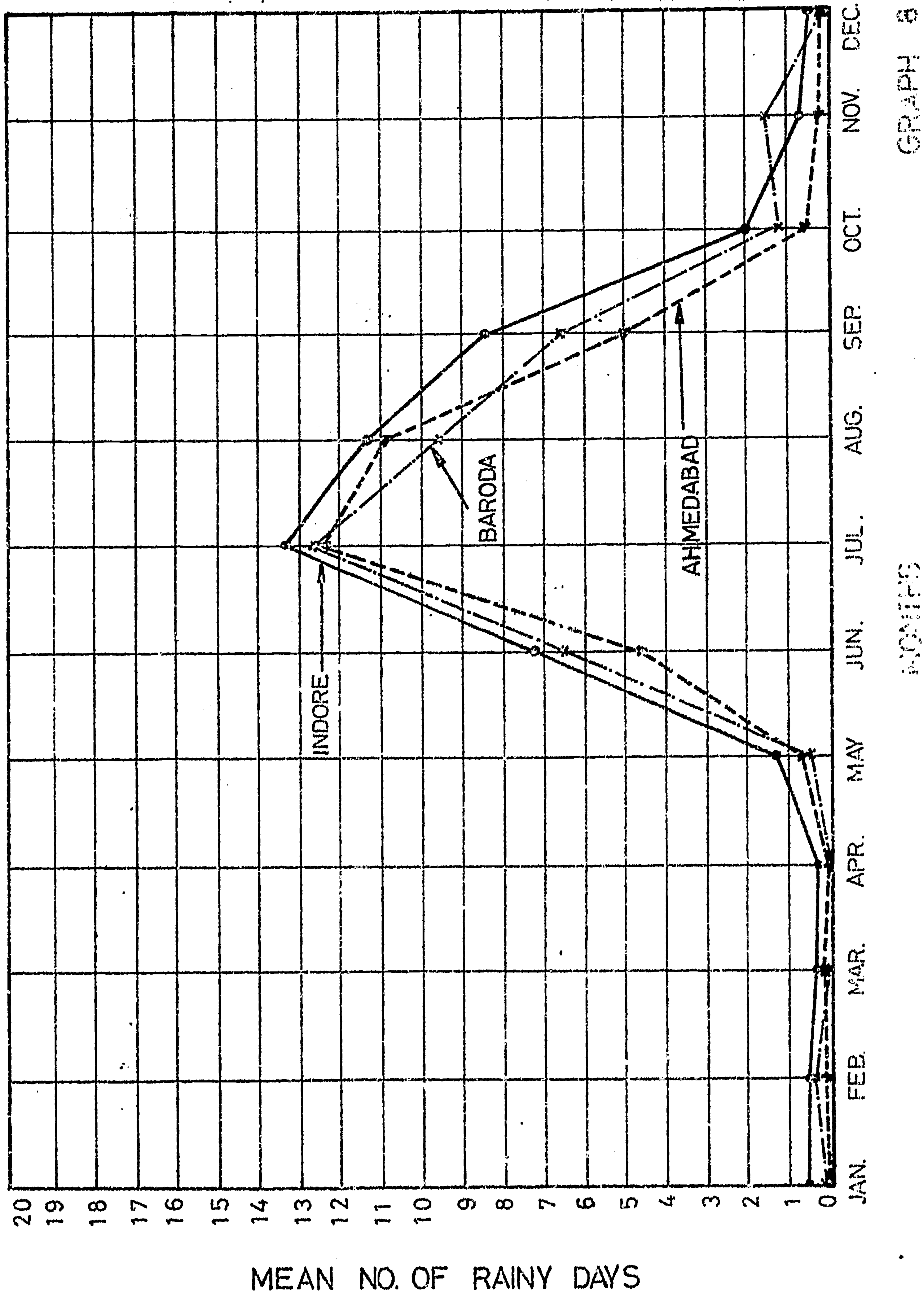
GRAPH 7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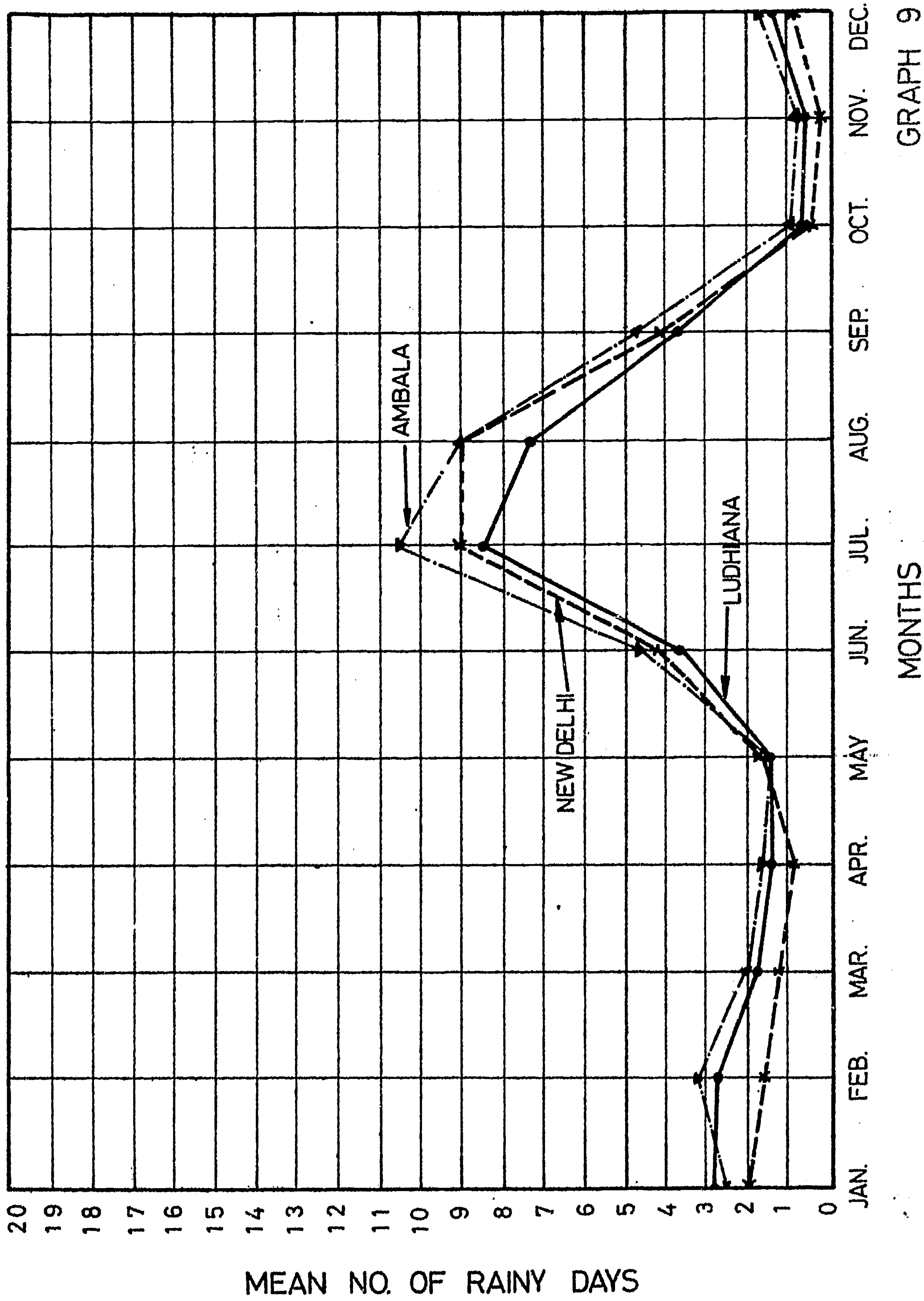
BARODA
AHMEDABAD
MONTHS

GRAPH 8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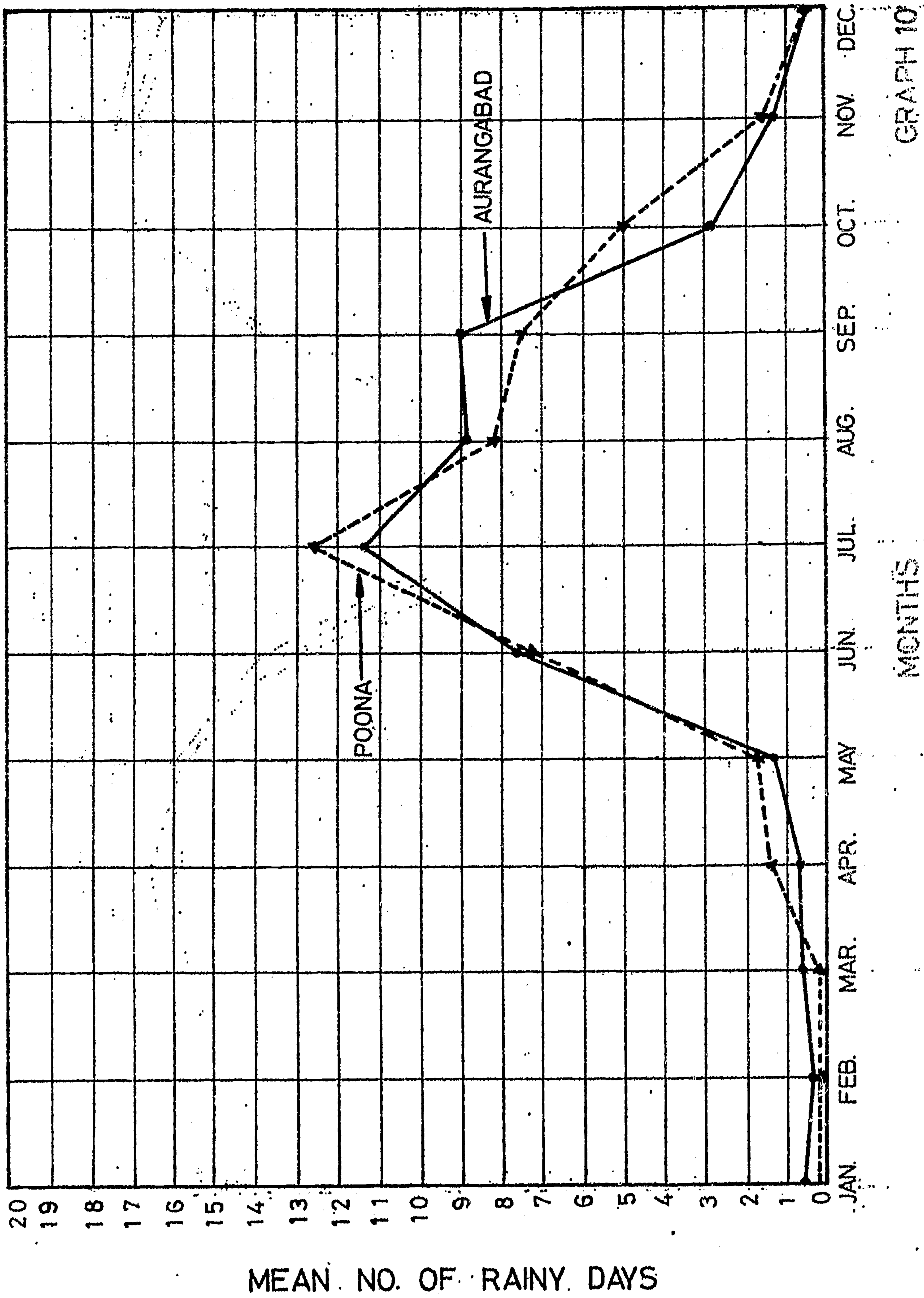
MEAN NO. OF RAINY DAYS

GRAPH 9


AURANGABAD
POONA
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
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MEAN NO. OF RAINY DAYS
MONTHS

GRAPH 10