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Cloud seeding trials at Delhi during monsoon months, July to September (1957—59)

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ABSTRACT. A programme of rainmaking trials during monsoon months (July to September), using the technique of dispersal in air of salt seeds of appropriate sizes from ground-based generators has been in operation at Delhi since 1957. The note presents the design and programme of the seeding trial, and the results obtained and experience gained in the course of the first three years of experimentation.

1. Introduction

The underlying principle of present day experiments on rainmaking by methods of cloud seeding is an attempt at modifying suitably the micro-physical features of a cloud, as would favour a few amongst the innumerable tiny cloud droplets to grow at the expense of their neighbours. All cloud particles cannot grow and become raindrops—there is not enough water in a cloud for the purpose—and a process of discrimination has to operate. Although adequate direct observation in clear verification of the theory is yet not available, it is now generally accepted that by helping the formation of a few 'giant' cloud droplets at and near cloud base, sea-salt nuclei carried by maritime air to areas even far into the interior of a continent play an important role in aiding rain formation in clouds in which Bergeron mechanism either does not operate or is effective only at a rather late stage of precipitation growth within them. To meet situations in which precipitation failures are due, principally, to deficient supply of such nuclei naturally, cloud seeding trials by 'warm' technique seek to stimulate coalescence growth of raindrops, by directly spraying water drops into clouds or by providing them artificially with 'giant' hygroscopic nuclei as would lead to production of cloud droplets of the required large sizes. This method of seeding is considered to be applicable particularly to rainmaking trials in clouds in tropical regions where rainfall, at least during summer months, is largely in the nature of showers from convective type clouds.

Scientifically designed experiments on rainmaking by methods of warm seeding have been conducted in different countries in recent years. The technique of water seeding from aircraft has been employed by Coons *et al.* (1948) and Braham *et al.* (1955) in the U.S.A., and by Bowen (1952) in Australia. Seeding trials by dissemination in cloud air of deliquescent salt particles have been conducted from aircraft in England (Mason 1953) and in South Africa (Anon. 1948), by balloon or rocket technique in East Africa (Davies *et al.* 1953, and Brasell and Taylor 1959); and from ground in France (Dessens 1950), in Japan (1954), and in Pakistan (Fournier D' Albe *et al.* 1955). While the results of these rather short series of trials have, on the whole, been encouraging, in as much as many of these have indicated a positive trend, a firm quantitative estimate of the efficacy of the methods in bringing about significant augmentation of rain over an area has not yet been possible.

For arriving at a dependable quantitative finding in regard to the results of such seeding trials, it is essential that these should be conducted on a fairly large scale and on a long term basis. Obviously, the simplest and most economical method to follow would be seeding based on use of ground generators, provided conditions obtaining in the area are favourable generally for the seeds released from ground to have a reasonable chance of reaching cloud levels in the desired concentration. Accepting, provisionally, the qualitative basis of such seeding treatment for rain stimulation in clouds in the tropics, a systematic programme of rainmaking trials by method of ground seeding has been taken up at Delhi (in northwest India) during the southwest monsoon season, since 1957. The method employed consists in spraying a dilute solution of common salt by using power sprayers, providing a source of supply of hygroscopic nuclei of appropriate sizes to be fed into cloud air. The details relating to the arrangements of the seeding trials and tentative results obtained during three seasons, 1957 to 1959, are presented in the paper.

2. Studies preliminary to planning of the experiments

Relevant meteorological features over and around Delhi were first studied, with a view to finding out if the conditions prevailing are suitable for conduct of seeding trials based on use of seed generators placed on the ground. The following aspects have been examined.

(*a*) *Natural concentration of hygroscopic nuclei in air*—Before embarking on a plan of cloud seeding by dissemination of hygroscopic nuclei in cloud air, it would be logical to try to make an estimate as to whether and, if so, how frequently the need for such artificial nucleation actually arises in the area in question. Necessary determinations of conditions obtaining in free air at cloud levels having not been possible, the study has been limited to estimate of concentration of hygroscopic particles of radius one micron and more in surface air layers over Delhi during two monsoon seasons, based on use of Cascade Impactor (May 1945). It has been found that, while concentration on certain days is as high as 50 per litre, this falls in many instances to about nil in a hundred litres of air sampled. Taking that similar large fluctuations occur also at cloud levels, and that failure of rain from some of the well developed cumulus clouds is due, at least partly, to deficiencies of giant hygroscopic nuclei in air, the area around Delhi appears suitable for the intended seeding trials.

(*b*) *Probabilities of seeds dispersed reaching cloud heights*—Following a method of telemetering pressure levels reached in successive minutes by a balanced balloon, after it was got detatched by a suitable time fuse device from a carrier balloon taking it up initially, an estimate was attempted of vertical currents in the lower air layers over Delhi during the monsoon season. From soundings made on a number of days it has been found that ascending currents of the order of 1/4 to 3/4 mps usually prevail in this layer during hot afternoon hours. Taking updraft rate as 1/4 mps, the released seeds would be expected to reach clouds, with base at a height between 1 and 1·5 km, in about an hour to an hour and a half.

(*c*) *Direction of wind and associated rainfall distribution around Delhi*—To find the directions in which seeds dispersed from ground would drift and, on being carried by updraft and reaching cumulus clouds, would help to influence rain processes in them, analysis was made of daily wind data during the monsoon season at Delhi for five years 1950 to 1954. Fig. 1 shows percentage frequencies of direction of mean wind from surface up to 2·5 km based on data for days of cloud and rain. It is seen that on the vast majority of such days the resultant wind in the layer mentioned (wind at 1·5 km has been found to provide a good index of this) is either from some southeasterly direction or is from the opposite quadrant, that is, from northwest.

The relative distribution of rainfall in the four sectors around Delhi up to a distance of 60 miles, corresponding to the four classes of days with wind at 1·5 km, from NE, SE, SW, and NW, was studied next. Analysis of data for 12 years, has shown (Srivastava 1958) that the distribution of rainfall is dependent on wind direction, and that the ratio of rainfall in any one sector to that in the sector

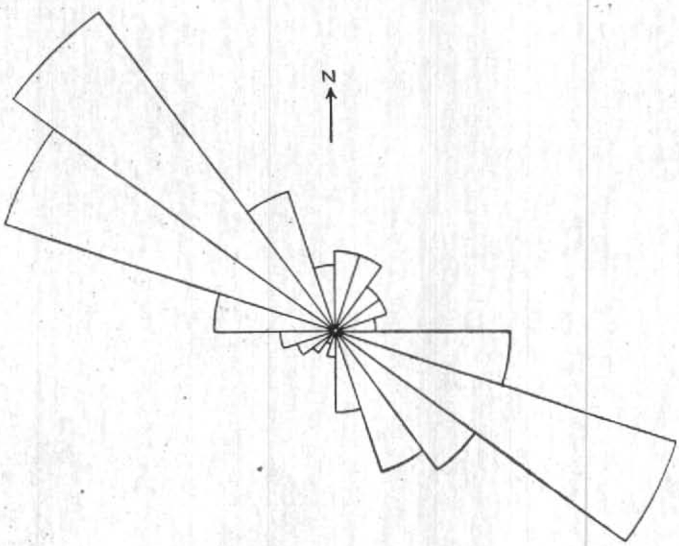

Fig. 1. Analysis of wind conditions over Delhi (1950—54)

opposite is highest when the wind is from the opposite quadrant, that is, when the sector lies downwind. It will be seen from Fig. 2 that, while the mean rainfall ratio (NW/SE) is 0·66 for days of NW'ly wind, this is 0·87 when the wind is SE'ly. The finding is of value, as it shows that so far as Delhi area is concerned, the mere fact that rainfall ratio downwind to that upwind during a particular seeding season is higher than the average for past unseeded years, based on data for all types of winds, cannot be taken as a safe criterion that the seeding has been a success. This also points clearly to the necessity of treating seeding trials at Delhi relative to the two sets of days with southeasterly and northwesterly wind at 1·5 km as two separate series of experiments, for purposes of assessment of results.

(*d*) *Fixation of target and control sectors*— On the basis of study of wind features as discussed above, it is seen that the target sector, that is, the area affected chiefly by the dispersed seeds, would lie to the northwest or southeast of the seeding site, according as the mean wind up to height of cloud base is from the one or the other of the two prevailing directions, namely, from southeast or northwest. The angular spread of the target area would be the same as the angular width of the plume of dispersed material, depending upon the turbulence structure of wind on the day in question. Under conditions of steady and nearly uniform wind, the angular spread would be limited to a few degrees only. Actually, however, due to superposition of vertical currents on the horizontal wind which often varies from level to level and also changes in the course of the seeding operation, a considerable widening of the plume and, as such, of target sector results. Considering these uncertainties and that our knowledge of the exact nature of turbulent diffusion of particles is still far from definite, a simplified assumption has been made that the target covers the entire 90° quadrant opposite to that in which the mean wind direction on any particular day lies. Thus, if the wind direction is from southeast (090°—180°), the northwest quadrant is taken to be the target and, *vice versa* when the wind is from

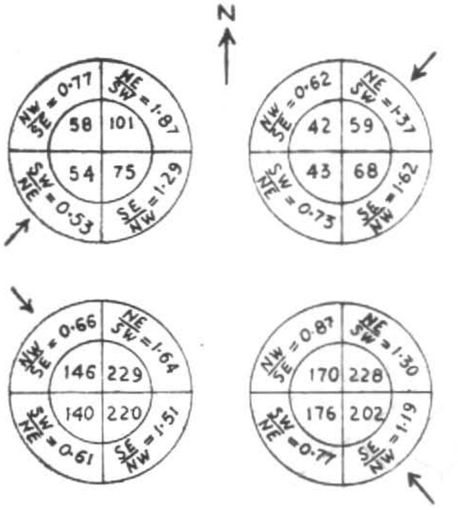

FIG. 2. DISTRIBUTION OF AVERAGE RAINFALL IN MM AND THEIR RATIOS IN FOUR SECTORS AROUND DELHI (1943-1955, EXCLUDING 1947)

The wind directions are shown by the arrows

the opposite direction. The fixed 90° spread assumed for the target is most probably an over-estimate and, being not centred about the mean wind direction, is not quite satisfactory. However, as will be seen from discussions on evaluation of seeding trials, the assumption made has an advantage in as much as it facilitates to a certain measure, separation of effects of natural variations in rainfall distribution over target and control sectors from those caused by seeding—the most important point to be borne in mind in coming to a conclusion about the results of such seeding trials.

In fixing the horizontal range of the target sector, the main consideration has to be given to probable concentration of dispersed seeds at different distances downwind. Taking the limit of effective distance as one at which seed concentration falls to a few tens per cubic metre, the range of the target sector has been taken as 25 km from the site of seeding. The limit so fixed is supported also on consideration of the average speed (2 to 2·5 mps) of lower level winds during afternoon hours in the monsoon season and of updraft at 1/4 mps, conditions under which seeds released from ground would reach cloud level at a distance of 10-15 km. However, with convective cloud fields lying in the path of diffusing material, where vertical currents would be much stronger and horizontal wind weaker, the seeds would reach cloud height at a much closer range. On considerations such as these, the target sector has been taken to extend from a short distance downwind up to 25 km from the seeding site.

To enable comparison of the rainfall which occurs in the target area during a given seeded period with what would have been if no seeding was done, we have to take into consideration the rainfall amount over a nearby area which is unlikely to have been affected by the dispersed seeds, that is, the 'control' sector. In selecting the control area care has, however, to be taken to see that rainfall there is well correlated to that in the target sector. With reference to seedings conducted at Delhi on days of northwesterly wind, when the target sector lies to southeast, we have three possible choices of the control sector, namely, an equal area lying to northwest, southwest or northeast and, similarly, for days when wind is from southeast and the target is to northwest. To see which of these three sectors would be the most satisfactory for purposes of comparison, correlations between rainfall amounts in the four sectors have been examined on the basis of past data. Number and distribution of available raingauges within 25 km around Delhi being not adequate for such determinations, the study as above was made with reference to rainfall over an extended area up to a distance of 100 km. If correlation between more extended sectors is found to be good, that between corresponding restricted sectors would, *a fortiori*, be also good. Average total rainfall amounts for three months, July to September, for each year (1918—1950), based on data for about seven raingauges in each sector, are plotted as dot diagrams in Fig. 3.

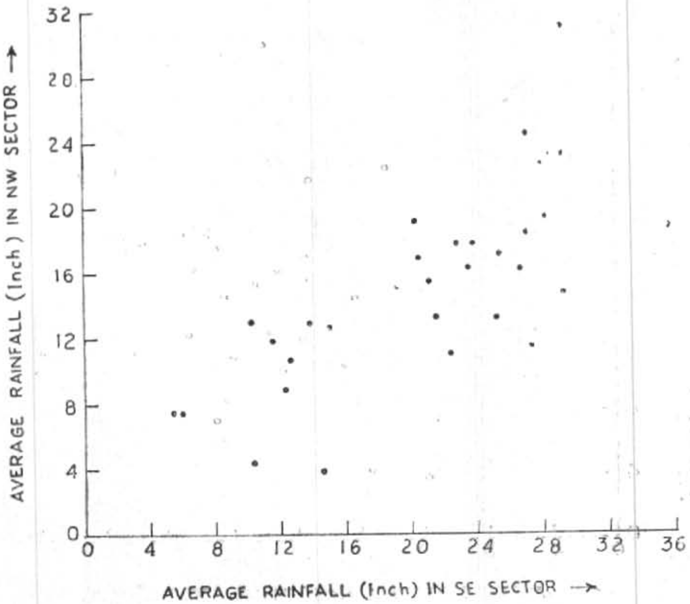

FIG. 3 (a)

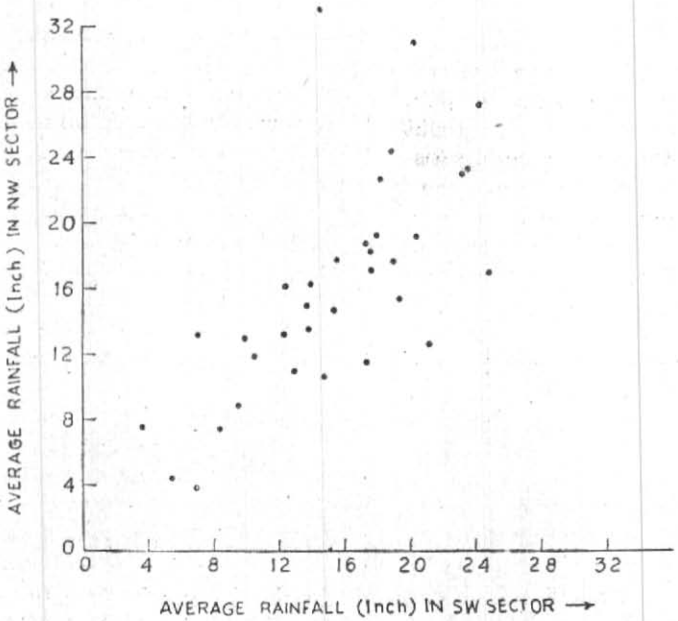

FIG. 3 (b)

DOT DIAGRAMS OF AVERAGE RAINFALL AROUND DELHI (1918-50)

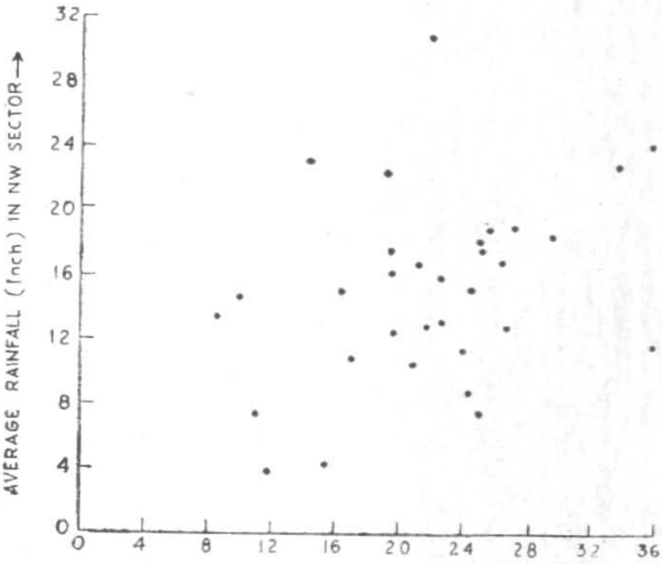

FIG. 3 (C) DOT DIAGRAM OF AVERAGE RAINFALL AROUND DELHI (1918-50)

It is seen that, while correlations between the three sectors, northwest, southwest and southeast are reasonably good, rainfall in northeast sector is not well correlated with that in other sectors. Leaving out the northeast sector, we thus have two control sectors, namely, the quadrant to southwest and the one lying upwind. Of these, the latter has been chosen as more dependable, as possibilities of this sector being affected by dispersed seeds are more remote.

3. Details of seeding operations

Hygroscopic seeds are fed into the lower air layers by spraying from ground dilute salt solution of known concentration, using two sprayers operating simultaneously for about 3 hours round about mid-day. Two types of spraying equipment have been used (*i*) Hudson Defender liquid sprayer, developing a pressure over 200 lb/sq. inch and having spraying capacity of about a gallon per minute, and (*ii*) Humber Model BN-3/HC, 5 H.P. air compressor operating at a pressure of 125 lb/sq. inch and spraying a gallon of solution in 5 to 6 minutes. The slower rate of dispersal by the latter equipment is compensated by more effective atomization of salt solution, as a result of which for the same quantity of solution sprayed, the number of droplets of small enough sizes as may get air-borne are greater. The salt solution is made in concentrations of one pound of salt in a gallon of water, such that the equilibrium relative humidity over the solution is about 95 per cent.

Size distribution of droplets produced by the sprayers of type (*i*) are shown in Fig. 4, from which it will be seen that, under updraft at 1/4 mps, quite a large proportion of sprayed droplets having sizes up to about 70μ diameter would be liable to be carried upwards with prospects of reaching cloud heights. Further, on occasions when relative humidity in sub-cloud layers is well below 95 per cent the droplets would shrink somewhat by evaporation and some amongst the larger droplets would also have a chance to move up. Salt contents in drops of diameter 20 to 70μ have dry masses ranging from 4×10^{-10} to 10^{-8} gm, or diameters from about 7 to 25μ, and are of right sizes to lead to production of required giant cloud droplets shortly after entry into a cloud.

On the basis of droplet size distribution as in Fig. 4, it is seen on calculation that total number of droplets of all sizes obtained by spraying a gallon of solution is of the order of 4×10^{10} and that, of these, about 75 per cent having diameter 70μ or less are likely to prove effective seed carriers. Spraying solution at 1 gallon/min, the rate of feed of such seeds comes to 3×10^{10} min^{-1} or 5×10^{8} sec^{-1}. Similar computations made on the basis of size spectra of droplets produced by the compressor also put the source strength at practically the same figure. With two sprayers operating at a time, the rate of seed dispersal is thus of the order of 10^{9} sec^{-1}. With our present rather incomplete knowledge of processes governing turbulent diffusion of aerosols under changing conditions of air motion, it is difficult to make a precise estimate of concentration of dispersed seeds at various distances from the source. A rough estimate of the order of value on the basis of (*a*) dispersal rate at source, (*b*) mean wind speed, and (*c*) relationship of inverse 1·76th power of distance, as suggested by Sutton (1953), gives the concentration at a distance of 25 km as about 200/m^3. The estimate as above, involving extrapolation over a considerable distance of a relationship which is founded on experimental determination of conditions within only a limited range, may not be quite dependable, particularly when we consider our target area to spread over as wide an angle as 90°. Actual concentration at a distance of 25 km under such conditions is unlikely to exceed 20 to 25/m^3.

4. Programme of seeding

The development of a reasonably satisfactory tool to help the separation, as far as possible, of natural variations in rain distribution from those caused by seeding has to

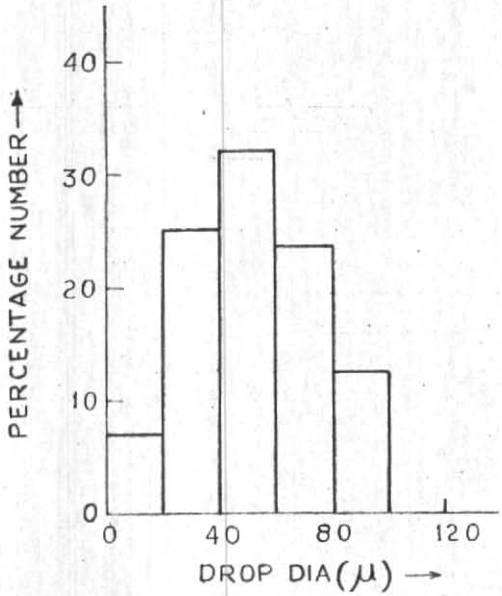

FIG.4. SIZE DISTRIBUTION OF DROPLETS FROM SPRAYER

be given the first consideration in the proper designing of scientific experiments on rain-making, particularly those based on indirect seeding of clouds by use of ground generators. The regression method adopted in many of the earlier experiments for comparison of target and control area rainfall has not been found quite dependable, and cannot also be used unless adequate historical data of rainfall for the two sectors are available. Considering such problems, the programme of seeding has been arranged on the basis of randomization—a scheme which, within its own frame work, provides essential control data for evaluation of the trials made.

Seeding has been done according to the advice obtained daily from the local Weather Forecasting Office, regarding (*a*) wind direction at 1 and 1·5-km levels, and (*b*) actual or expected cloud conditions, and probabilities of rain occurrence over and around Delhi during the next 12 hours.

TABLE 1

Number of seeded and not-seeded days

	Wind from SE		Wind from NW	
	Seeded	Not-seeded	Seeded	Not-seeded
1957	10	13	9	3
1958	21	17	11	7
1959	21	18	11	11

A day with wind at 1·5 km from SE or NW sector and expected development of low clouds, particularly of cumuliform type in amounts 3 oktas or more, is classified as 'seedable'. If forecasts of weather are such that the day is to be treated as suitable for seeding, the operator proceeds with the seeding operation or does not seed, according to a randomized procedure controlled by figures as in a series of random numbers, picked up from a book on Statistical Tables before commencement of each seeding season. A day with persistently overcast sky with low cloud, or one on which rain occurs frequently or continuously during mid-day period has also been treated as "unseedable" in this programme of randomised seedings. It may be added that the principle of randomization could not be followed rigidly during the first seeding season, that is, in 1957.

Table 1 gives the number of 'seeded' as against 'not-seeded' days amongst those considered 'seedable' in each of the three years 1957 to 1959.

5. Evaluation of seeding trials

To assess results, comparison is made of the ratio T/C of rain over target to that over control sector, relative to the two groups of seedable days—one seeded and the other not-seeded. The number of existing rain-gauges within a radius of 15 miles around the seeding site being inadequate to give a correct representation of rainfall distribution in the various sectors, 28 additional rain-gauges were set up to form a close network of such stations. A higher ratio value for seeded days compared to that for not seeded, is taken as suggestive of a positive result, that is, that seeding apparently had an effect in inducing more rain in the target area than what might have occurred otherwise. Wide variations in natural distribution of rainfall and consequent large scatter of T/C values from day-to-day render it difficult for any reasonable conclusion to be drawn on the basis of the ratio on individual days, and an averaging of data becomes necessary to make the results more easily discernible. Accordingly, rainfall data for the two sets of days have been grouped monthwise, and comparisons made of mean T/C ratios based on average total rainfall per station on seeded and not-seeded days in each month. For this purpose, seeding trials conducted during the same month, but on the two different classes of days with prevailing lower level winds from southeast and northwest, for which the relative positions of target and control sectors get interchanged, are treated as belonging to two different series of trials and evaluated separately. Thus, with 6 series of trials in each season, we have results of 18 trials units in all to consider for the 3-year period under review.

Table 2 (a) gives the mean T/C ratios for each month, relative to seeded and not-seeded days under conditions of southeasterly winds, while Table 2 (b) gives similar data for days with northwesterly winds.

It will be seen that out of 9 trial series belonging to the first set, the results of 7 are positive, of one negative and of 1 indeterminate, and that in the case of the second set 5 gave positive results, 1 negative and 3 were indeterminate. Thus, in all, out of 18 trial units under examination, 12 have shown a positive tendency, 2 negative, and 4 are inconclusive. Although the results as above, viewed in a broad way, seem significant, the reliability of the conclusions reached gets greatly handicapped as we note the large differences in mean T/C values for non-seeded days in different months. With a view to minimising uncertainties due to such random variations

TABLE 2

Rainfall (mm) per station in target *T* and control *C* sectors

Month and year	Seeded			Not-seeded			Results
	T	*C*	*T/C*	*T*	*C*	*T/C*	
(a) Wind from SE							
July 1957	85·3	106·2	0·803	0	15·0	0	Positive
August	16·0	0	0	50·8	27·2	1·867	Do.
September	3·3	7·1	0·465	25·9	68·1	0·380	Do.
July 1958	15·0	36·6	0·410	24·4	86·4	0·282	Do.
August	0	0	Ind.	60·7	75·7	0·802	Indeterminate
September	69·8	90·2	0·774	4·8	8·9	0·539	Positive
July 1959	31·2	34·0	0·918	27·2	30·0	0·907	Do.
August	20·1	4·8	4·190	17·0	5·1	3·330	Do.
September	38·1	34·0	1·120	40·9	17·5	2·337	Negative
(b) Wind from NW							
July 1957	24·1	9·1	2·650	8·9	30·2	0·295	Positive
August	0	0·2	0	0	2·8	0	Indeterminate
September	0	0	Ind.	0·2	1·3	0·154	Do.
July 1958	32·8	33·5	0·979	3·3	5·6	0·589	Positive
August	25·9	24·9	1·040	28·2	29·2	0·966	Do.
September	0·2	0·5	0·400	2·5	0·2	12·500	Negative
July 1959	16·3	9·6	1·698	36·3	30·2	1·202	Positive
August	54·6	52·8	1·034	33·0	42·9	0·769	Do.
September	0	0	Ind.	18·5	13·2	1·402	Indeterminate

TABLE 3

Actual, as against expected, rainfall (mm) in target sector during seeded period

Period ending	Cumulative rain per station		Difference	Percentage difference
	Actual	Expected		
(a) Wind from SE				
September 1957	104·6	78·7	25·9	33
September 1958	189·4	142·1	47·3	33
August 1959	240·7	185·7	55·0	30
September 1959	278·8	235·9	42·9	18
(b) Wind from NW				
September 1957	24·1	2·5	21·6	864
September 1958	83·0	42·4	40·6	96
August 1959	153·9	103·0	50·9	49
September 1959	153·9	109·8	44·1	40

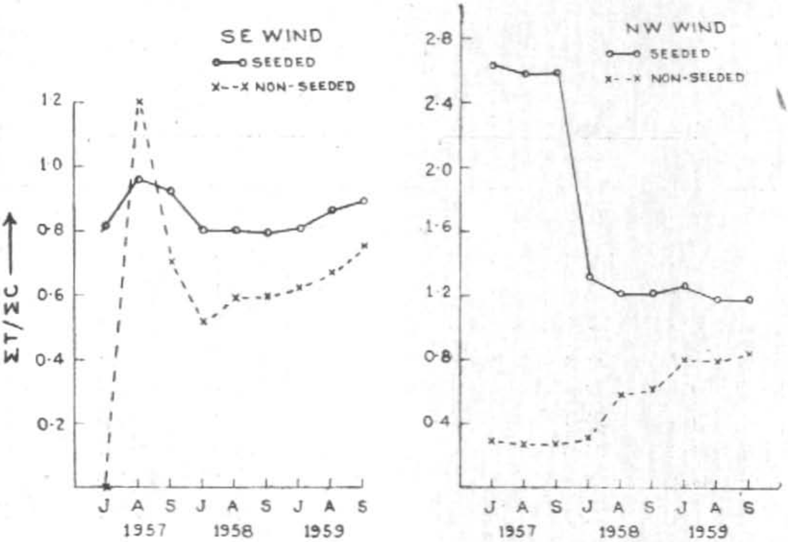

FIG. 5. RATIO OF CUMULATIVE VALUES OF RAIN IN TARGET AND CONTROL SECTORS AT VARIOUS STAGES OF TRIALS

in the values of the ratio relative to individual trial units, the trend of results has further been examined on the basis of progressive values of $\Sigma T/\Sigma C$ as the trials proceeded, following the method of evaluation of aircraft-based seeding experiments in Snowy Mountain regions in Australia (Adderley and Twomey 1958). The cumulative ratio values for seeded and not-seeded days belonging to the two different wind groups are shown as plotted in Figs. 5(a) and 5(b). It will be seen that although at initial stages the curves show somewhat irregular variations, and differences in the values of their ordinates rather too large to be accounted for as being due principally to seeding, the separation between them becomes more regular later, with the curve for seeded days lying above that for days of no seeding, indicative of a positive tendency. However, a trend of the two curves approaching each other towards the end is noticeable and it is, therefore, difficult to come to a fully dependable conclusion until the trials have been carried out for a long enough period.

Making an assumption that in the absence of seeding average T/C ratio for seeded days during a given month or a season would be about the same as that for corresponding non-seeded days, one could attempt an estimate of what the rainfall would be in the target area if no seeding had been done, on the basis of rain in control sector on those days. Although such an assumption may not be tenable in view particularly of the large scatter of the values of the ratio for different groups of non-seeded days, a tentative examination of data has been made on this basis to get a preliminary idea of the probable quantitative effects of seeding done during the period in question. Table 3 [(a) and (b)] gives the actual, as against the expected total rainfall in the target sector, and also their percentage differences at successive stages of seeding trials on the two sets of days with winds from SE and NW sectors respectively. In computing these, rainfall for all the three months in a season has been considered together, except that in the year, 1959, the results up to the end of August have also been shown in addition to those till the end of the season, that is, till September. It will be seen that in the case of seeding trials relative to days with winds from SE sector, the positive difference of 30 per cent between actual and expected rainfall upto the end of August 1959, drops to 18 per cent only when the rather large negative result of September seedings in that year is taken into account, demonstrating clearly the difficulties and uncertainties of evaluation of indirect seeding experiments conducted from ground during a few seasons only. The figures as in Table 3 (b) in respect of seedings done on days with winds from NW sector indicate a net increase of rainfall by 40 per cent. Considering seedings on both the classes of days together, the indicated increase for the entire three year period works out to 25 per cent. However, if we omit figures for the first season, 1957, when randomization procedure was not followed rigidly, the percentage increase comes to about 10 per cent.

6. Concluding remarks

Judging from the geographical situation and prevailing cloud and rainfall features, the area around Delhi lying on the borders of the semi-arid zone of Rajasthan, more than 600 miles away from the nearest sea, is no doubt a suitable location for trying out rain stimulation experiments by salt seeding techniques during monsoon months. Moderate cloud cover during the season by clouds largely of cumuliform type, permitting a fair degree of insolational heating of ground and consequent up currents in lower air layers on most afternoons is also a factor which favours attempted nucleation of clouds aloft by seeds released from the ground. A rigorous testing of the method followed is, however, not easy, because of lack of control over dispersal of seeds into clouds of right type and at the right moment and also of the difficulties, as are common to all rainmaking trials, of separating out effects of natural variations in rainfall from those caused by seeding. Despite the principle of randomization followed in the programme of experiments, it is not possible to ensure a proper balancing of similar meteorological situations between the two sets of days, 'seeded' and 'not-seeded', unless trials have been repeated for a large number of seasons. The longer has to be the period of study, the smaller is the order of rain augmentation expected by such acts of seeding.

Despite the large number of rainmaking trials conducted in recent years in various parts of the world, no satisfactory quantitative basis has as yet been found to determine the efficacy of a particular mode of cloud seeding under conditions obtaining in a given region. A reasonable estimate of possible increase in rainfall in an area by the method of 'warm' seeding could be made if we knew what proportion of warm clouds there give rain naturally and what their contribution to the season's total rainfall is. Although no such determinations by direct observations have been possible, Ramana Murty *et al.* (1960), on the basis of radar study of precipitation features of rain cells of different types within 100 km around Delhi and certain assumptions about rainability of warm clouds there, came to the tentative conclusion about possible augmentation of rain to the maximum of 18 per cent during monsoon season, provided all eligible clouds could be effectively seeded by warm technique. In the rainmaking trials under review, seeding has been attempted from the ground and during a certain restricted period of the day only, conditions under which even the most optimistic expectation of increase in rainfall by such means would not exceed 10 to 15 per cent. Considering this and also the rather large variability of natural rain distribution, it is essential that trials extending over a number of seasons are carried out in order that effects of variations due to natural causes might be allowed for suitably. With a view to reducing the period of study as much as possible, additional seeding centres have been started recently at two nearby stations, namely, at Agra and Jaipur. The seeding programme at these centres is essentially the same as that at Delhi. It is hoped that, with available data relating to trials at all the three stations, it may be possible to come to a dependable conclusion about the usefulness of salt seeding in the area, after experiments have been conducted for 3 to 4 years more.

7. Acknowledgement

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