

AN OPERATIONAL RAIN STIMULATION EXPERIMENT
USING WARM TECHNIQUE OVER RIHAND CATCHMENT
IN NORTHEAST INDIA DURING SUMMER MONSOONS
OF 1973 and 1974

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ABSTRACT

Experiments, using warm seeding technique, on operational basis, were conducted during 2 summer monsoons of 1973 and 1974, over the 13,000 sq. km catchment area of the Rihand reservoir in the state of Uttar Pradesh, India.

In the first year of operation, seeding was not done on many seedable days when flying could not be undertaken. Considering those not-seeded days as control days and nearly equal areas adjoining the eastern and western boundaries as control areas, the result was evaluated by using 24 hours rainfall data from the ordinary raingauges functioning in all the areas. In the second year of operation, seeding was not done, in general, on every fifth seedable day which was considered as control day. Seeded days, which were nearest to the control days, were considered as experimental days for evaluation. The result was evaluated by using 24 hours rainfall data from the ordinary raingauges and 5 hours rainfall data from the self-recording raingauges.

The analysis suggested an increase in rainfall in the catchment area upward of 16 percent, which is statistically not significant.

Microphysical measurements were made concurrently with the seeding operation. A summary of the measurements is presented.

1. INTRODUCTION

The water level of the Rihand reservoir ($24^{\circ}12'N$, $83^{\circ}03'E$, 310.5m MSL) in the state of Uttar Pradesh touched a low value before the summer monsoons of 1973 and 1974, resulting in acute shortage of power generation in that state. On request by the state government, a rain stimulation experiment was undertaken in the 13,000 sq. km catchment area of the reservoir. The technique used in the experiment was warm seeding by salt particles.

The results of the experiment for the first year were published (Kapoor et al., 1974). The results for the second year are now available

and these are reported in the present paper. The design of the experiment and the results for the first year are also briefly mentioned.

In the course of the experiment a number of isolated clouds in the catchment area were repeatedly seeded. Droplet size distributions were obtained in some of those clouds before and after seeding. Measurements were also made of the electrical conditions in some clouds before and after seeding. A summary of the measurements made is given.

2. DESIGN

(a) Target Area

The entire catchment covering an area of about 13,000 sq. km was the target area (vide Figure). The reservoir, which is about 470 sq. km in area, is situated near the northern border of the catchment.

(b) Control areas

Two regions, each covering about the same area as the catchment and adjoining its eastern and western boundaries, were considered as two independent control areas. These areas are designated as C_E (east-control) and C_W (west-control).

(c) Rainfall correlation

The rainfall in the target area is highly correlated with that of the east-control area ($r = 0.84$) and also with that of the west-control ($r = 0.89$).

(d) Seeding material

The material used for seeding, consisted of common salt and soapstone taken in the ratio 10 : 1 and ground to a fine mixture with mode particle diameter of about 10 microns.

(e) Seeder aircraft, base of operations and rate of seeding

The seeder aircraft was a DC-3. It was fitted with a specially designed salt dispensing gadget (Krishna et al., 1974). The base of operations was Varanasi ($25^{\circ}27'N$, $82^{\circ}52'E$, 85 m MSL).

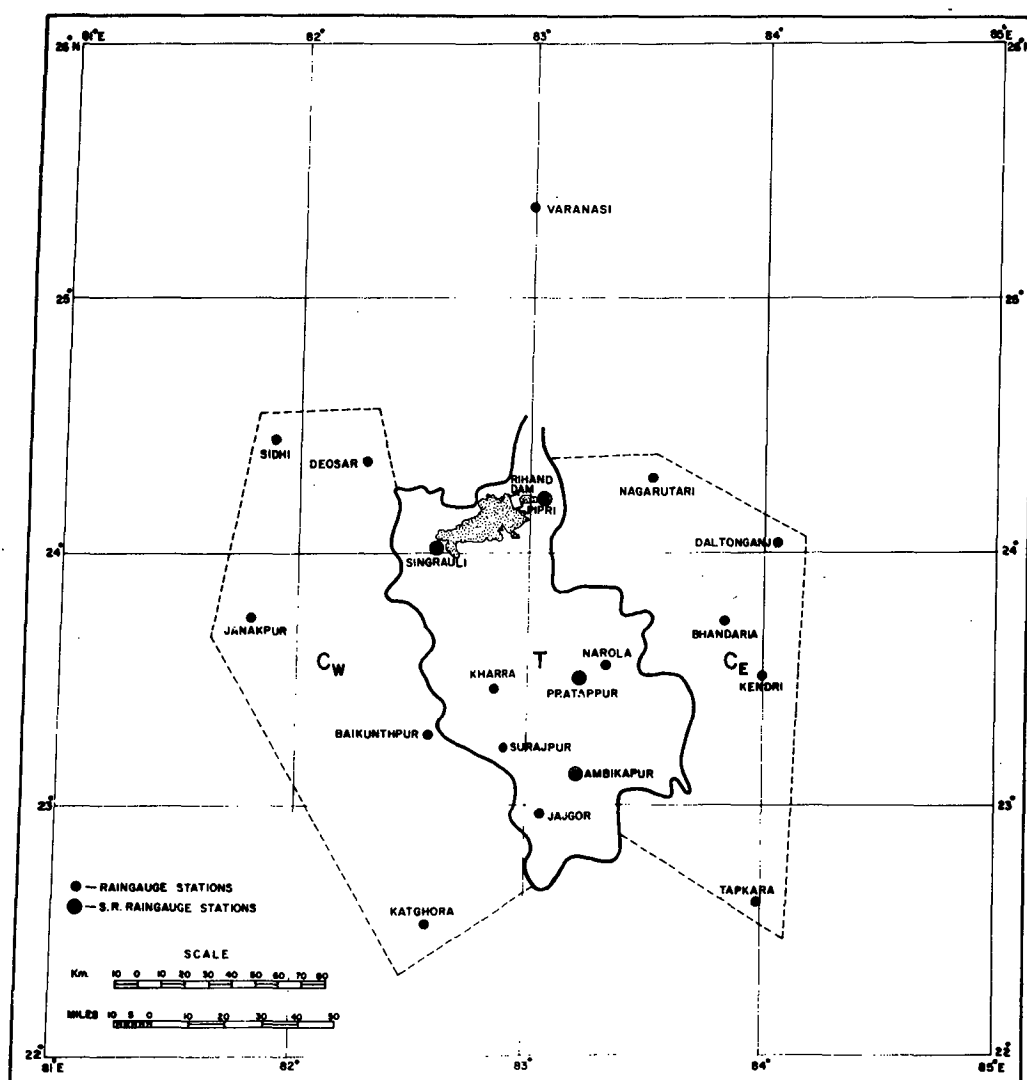
The rate of seeding varied from 12 to 15 kg per 3 km of flight path. The total amount of material released in a seeding flight ranged up to 1975 kg.

(f) Seedability criteria

If three of the following four conditions were satisfied the day was considered seedable.

- i) The area forecast issued for the catchment should point out development of 3 octa or more of cumulus clouds.
- ii) The upper wind from 1 km to 3 km should be nearly steady. They may be

FIGURE: Locations of target area, T, and control areas, C_E and C_W . T is the Rihand catchment and the reservoir is shown stippled.



all either easterly (046° to 135°) or southerly (136° to 225°) or westerly (226° to 315°) or northerly (316° to 045°).

iii) The morning tephigram for the station Varanasi should indicate dew point depression not exceeding 5° to 700 mb and below.

iv) Current weather report for Ambikapur, a station inside the catchment, should show presence of low clouds over the region.

(g) Flight path, duration and level of seeding

The flight path followed for seeding was always inside the catchment. The route flown was dependent upon the wind at and above the level of seeding. The flight usually commenced by 1300 IST.

The duration of flight ranged up to 5 hours 45 minutes. The duration of seeding ranged up to 3 hours 40 minutes.

Seeding was done at levels between 1.5 km and 2.1 km above mean sea level, which corresponded to a few tens to a few hundreds of meters above cloud base.

(h) Seeded and not-seeded days.

In the first year the experiment was conducted on all the seedable days when flying became possible. In the second year the experiment was conducted according to a pattern wherein, generally, the fifth seedable day was left unseeded.

3. RESULTS

(a) Monsoon of 1973

The experimental period was from 5 August to 30 September. All the 61 days of the period satisfied the seedability criterion. The experiment was conducted on 34 days. The remaining 27 days, when the experiment was not conducted, were considered as control days.

Ordinary raingauges which measure 24 hours total rainfall, were the data source for the analysis. Data were available from 4 raingauges located at Singrauli, Kharra, Surajpur and Ambikapur in the target area and from 5 raingauges each in the two control areas, C_E and C_W , as shown in the Figure. The total rainfall, in mm, per station in the target area and the control areas on seeded and not-seeded days and the ratio values thereof are given in Table 1. The analysis suggested that the rainfall in the target area increased by 17.3% with respect to the east-control, C_E and by 28.6% with respect to the west-control, C_W . The increases are not statistically significant.

(b) Monsoon of 1974

The experimental period was 21 July to 5 October. There were 57

TABLE 1
TOTAL RAINFALL IN mm PER STATION IN TARGET AREA (T) AND CONTROL
AREAS C_E (east-control) AND C_W (west-control) ON SEEDED AND NOT-
SEEDED DAYS AND RATIO VALUES THEREOF FOR 1973.

Seeded days (s)					Not-seeded days (ns)			Double ratio			
$T(s)$	C_E	C_W	$\frac{T(s)}{C_E}$	$\frac{T(s)}{C_W}$	$T(ns)$	C_E	C_W	$\frac{T(ns)}{C_E}$	$\frac{T(ns)}{C_W}$	$\frac{A}{B}$	$\frac{C}{D}$
			(A)	(C)				(B)	(D)		
401.66	311.48	314.58	1.289	1.277	357.68	325.40	360.40	1.099	0.993	1.173	1.286

seedable days out of which 12 were left unseeded according to the procedure mentioned. These constituted the control days. The 12 seeded days which were nearest to the control days constituted the experimental days for evaluation.

Data were available from 4 additional ordinary raingauges and also from 4 self-recording raingauges in the target area (vide Figure). As far as the control areas are concerned data were available from the 5 raingauges in the west-control area, C_w , only. Assessment was done using 24 hours data from the ordinary raingauges and also 5 hours data from the self-recording raingauges.

i) Ordinary raingauges

The rainfall, in mm, per station in the target area and the west-control area for the control days and for the experimental days is given in Table 2 date-wise. The total rainfall, in mm, per station in the target area and the west-control area on the seeded and not-seeded days and the ratio values thereof are given in Table 3. The analysis suggested that the rainfall in the target area increased by 16.4%. The increase is not statistically significant.

ii) Self-recording raingauges

Data of self-recording raingauges are available for the target area. The procedure adopted for analysis was, therefore, to compare the ratios, for seeded and not-seeded days, of the rainfall recorded during the experimental period to that recorded during what may be called control periods which are of similar duration as the experimental period but which precede and follow that period.

The experimental period considered for the purpose was from 1300 to 1800 IST. The control period considered was of 10 hours total duration, which comprised 5 hours before commencement, 0700 to 1200 IST and 5 hours well after cessation of the experiment, 2200 to 0300 IST.

The values of average rainfall per station during the experimental and control periods were evaluated from the self-recording rain-gauge charts for the seeded and not-seeded days. These are tabulated in Table 4. The ratio values are given in Table 5.

The analysis suggested that the rainfall during the experimental period increased by 16.5 percent. The increase is not statistically significant.

4. MICROPHYSICAL MEASUREMENTS

- i) When suitable isolated clouds were observed in the target area, they were often subjected to repeated seeding. Cloud droplet spectra were obtained in a few cloud cases before and after seeding by traversing through them a number of times at nearly the same level above the cloud

TABLE 2

AVERAGE RAINFALL IN mm PER STATION IN TARGET AREA (T)
AND WEST-CONTROL AREA (C_W) ON SEEDED AND NOT-SEDED DAYS

Date 1974		T	C_W
Seeded days			
July	23	12.62	10.08
	28	5.30	16.64
Aug.	2	0.21	0.60
	7	6.23	3.22
	12	2.36	4.76
	14	6.36	8.12
	20	0.43	2.80
	25	7.74	0.64
	28	5.61	0.00
Sept.	11	0.73	0.00
	19	5.92	0.76
	20	2.60	1.28
Not-seeded days			
July	22	2.25	7.40
	27	7.83	11.86
Aug.	1	3.75	10.24
	6	13.24	16.08
	11	9.80	5.36
	15	22.23	31.54
	19	10.60	0.94
	24	18.98	16.18
	29	0.00	0.20
Sept.	12	0.03	0.00
	16	0.03	3.00
	18	12.48	0.00

TABLE 3

TOTAL RAINFALL IN mm PER STATION IN TARGET AREA (T) AND
CONTROL AREA C_W (WEST-CONTROL) ON SEEDED AND NOT-SEEDED DAYS
AND RATIO VALUES THEREOF FOR 1974

Seeded days (s)			Not-seeded days (ns)		Double ratio	
T(s)	C_W	$\frac{T(s)}{C_W}$	$T_{(ns)}$	C_W	$\frac{T_{(ns)}}{C_W}$	$\frac{A}{B}$
		(A)			(B)	
56.11	48.90	1.147	101.22	102.80	0.985	1.164

TABLE 4

RAINFALL IN mm PER STATION IN EXPERIMENTAL AND
CONTROL PERIODS ON SEEDED AND NOT-SEEDED DAYS

Date 1974	Experimental period	Control period
July	Seeded days	
23	6.70	0.18
28	0.45	0.65
Aug. 2	0.00	0.45
7	0.77	4.30
12	0.00	0.00
14	0.67	1.23
20	0.10	1.03
25	0.00	7.67
28	0.00	0.00
Sept. 11	0.40	0.00
19	5.23	0.00
20	0.77	0.70
Not-seeded days		
July 22	0.00	0.18
27	5.00	0.53
Aug. 1	5.90	0.50
6	2.00	16.10
11	0.00	0.23
15	6.70	5.40
19	0.00	0.00
24	4.93	13.47
29	0.00	0.00
Sept. 12	0.00	0.00
16	0.00	0.00
18	4.57	0.00

TABLE 5

TOTAL RAINFALL IN mm PER STATION IN EXPERIMENTAL
AND CONTROL PERIODS ON SEEDED AND NOT-SEEDED DAYS AND
RATIO VALUES THEREOF FOR 1974

Experi- mental period E(s)	Seeded days (s)		Not-seeded days (ns)		Double ratio	
	Control period C	$\frac{E(s)}{C}$	Experi- mental period E(ns)	Control period C	$\frac{E(ns)}{C}$	$\frac{A}{B}$
		(A)			(B)	
15.09	16.21	0.931	29.10	36.41	0.799	1.165

base. The results of the measurements were reported (Kapoor, et al., 1975, 1976). The values of median volume diameter and liquid water content increased remarkably in certain cases following seeding. The increases noted ranged up to 372% and 160% respectively.

- ii) Electrical measurements were also made in a few cases before and after seeding. Details are being separately reported (Ramachandra Murty et al., 1975). Following seeding, the field remained positive in the clouds which either did not develop rain or dissipated. The field underwent reversals in the cloud which developed heavy rain following seeding. The droplet charges showed no marked difference before and after seeding.

5. CONCLUSIONS

An operational rain stimulation experiment, using warm technique, was conducted over the Rihand catchment in the State of Uttar Pradesh during the summer monsoons of 1973 and 1974. Microphysical measurements were also made in a few cases of isolated clouds before and after seeding.

The results of the experiment for 1973 was evaluated using data from ordinary raingauges and that for 1974 using data, from both ordinary and self-recording raingauges. The analysis suggested that rainfall in the catchment during the period of seeding increased upward of 16 percent. The results are not statistically significant.

6. ACKNOWLEDGMENTS

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