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# Desert locust (*Schistocerca gregaria Forsk*) infestation in relation to meteorology and sunspot cycles in India during 1945-1980

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**सार** — पश्चिमी भारत में विभिन्न चरणों में मरू टिड्डी (सचीसटोसेरसा ग्रीगेरिया फोरस्क) के प्रादुर्भाव के जीवन काल में सिनॉप्टिक माप की मौसम विज्ञान प्रणाली की भूमिका को समझने के लिए 1945 से 1980 तक की अवधि के दौरान टिड्डी स्थिति संबंधी आंकड़ों और सिनॉप्टिक विक्षोंभों का विश्लेषण किया गया है । सात स्थानों पर अण्डें देने, टिड्डी, प्रकीर्ण एडल्टों और उनके दलों के उत्पीड़न के पाक्षिक आंकड़ों के विश्लेषण से पता चलता है कि इन गतिविधियों का कालानुक्रमी क्रम में मानसून-पूर्व वर्षा सहित सामान्य मानसून आरंभ के स्थानिक प्रगति का अनुसरण करता है। फिर भी, अगस्त के पहले पखवाड़े में टिड्डी दल को सबसे अधिक सक्रिय पाया गया ।

अच्छे आंकड़ों वाले एक स्टेशन पर विभिन्न अवस्थाओं में टिड्डियों की गतिविधियों के साथ विभिन्न प्रकार के मौसम वैज्ञानिक विक्षोंभों का कितना संबंध है इस बात को जानने के लिए साधारण रेखिक सह-संबंध तकनीक का प्रयोग किया गया था। यह देखा गया कि अंडे देने की गतिविधि वर्षा के साथ-साथ चली है और चरम सीमा के मध्य वर्षा में थोड़ी सी कमी से इसकी सक्रियता पर कोई प्रभाव नहीं पड़ा। टिड्डी के जन्म की चरम सीमा सामान्यतः वर्षा के एक महीने बाद दिखाई दी है। प्रकीर्ण एडल्टों की सक्रियता का वर्षा के साथ कोई खास सम्बन्ध नही देखा गया। दलों की सघनता, अगस्त और सितम्बर के पहले पखवाड़े के दौरान सबसे अधिक थी। वर्षा कराने वाली मुख्य मौसम वैज्ञानिक प्रणालियां थी – पश्चिमी विक्षोभ, अरब सागर में दबाव और भूमि पर विकसित कुछ दबाव ।

यह भी देखा गया कि टिड्डी दल के उत्पीड़न और सूर्य कलंक की संख्या के मध्य नकारात्मक सह-संबंध विद्यमान रहता है।

ABSTRACT. To know the role of meteorological systems of synoptic scale in outbreaks of desert locust (*Schistocerca gregaria Forsk*) at various phases of its life cycle in western India, data on locust situation and synoptic disturbances during period from 1945 to 1980 were analysed.

The analysis of the fortnightly data of the infestation of egg layings, hoppers, scattered adults and swarms for seven stations shows that the chronological orders of these activities follow the spatial progress of the normal monsoon onset with pre-monsoon rains. However, the highest swarm activity was found in the first fortnight of August.

Simple linear correlation technique was used to know the degree of association of various meteorological disturbances with locust activity at different stages for a station with good record of data set. The egg-laying activity was parallel with rainfall and slight decrease in rainfall between peaks did not affect the activity. Hopper emergence peaks were seen generally after a month of rainfall. Scattered adults activity showed no good association with rainfall. The swarms intensity was highest during first fortnight of August and September. The main meteorological systems causing rainfall were western disturbances, depressions over Arabian Sea and a few depressions developed over land.

It was also found that a negative correlation exists between swarm infestation and sunspot number.

## 1. Introduction

The role of meteorology in the outbreaks of locusts and their control, is well recognised. The soil temperature and its moisture content decide the incubation period. The availability of food after precipitation is essential for the hopper growth in all instars. The sexual maturity and migration of locust depend upon the air temperature, saturation deficiency of atmosphere, upper air speed and direction, and solar radiation over earth's surface. The understanding of the relationship between locust activity and meteorological parameters may be of great value to forecast the outbreaks of locust in a region. With this object in view, a study of the past 36 years records of locust invasion in relation to different rain producing synoptic disturbances occurring in India has been made.

The sun is the source of energy for any terrestrial phenomena associated with locust activity, so we can expect possibility of an indirect solar control on locust infestation also. The periodic recurring cycle of locust infestation in India (Rao 1940) and Philippines (Uichanco 1936) are well known, and these cannot be explained by mere local climatic variations. Uvarov (1931) observed synchronous appearance of locust in India during 1915-16 and 1927-30 which might, perhaps, be connected with sunspots. However, periodicity in infestation of various locust

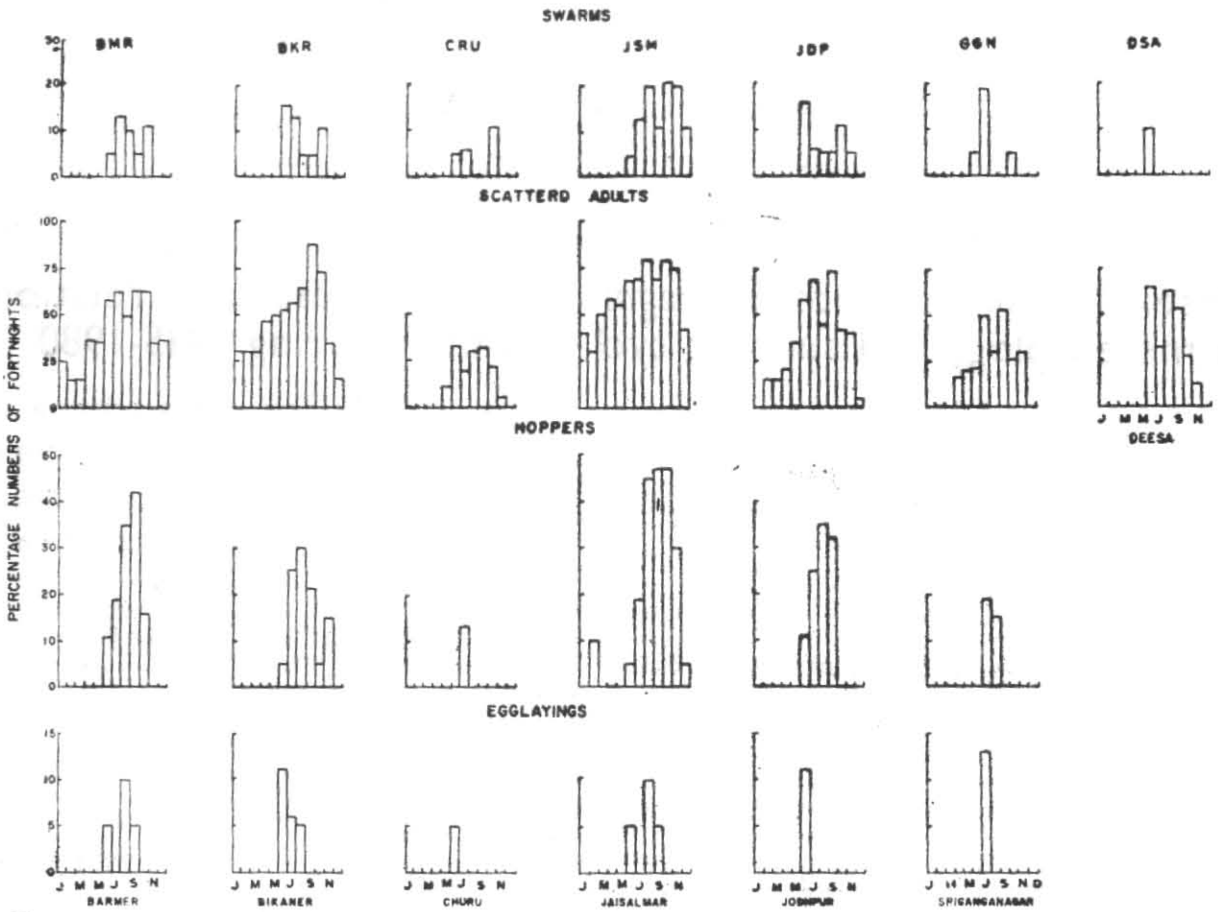


Fig. 1. Percentage number of fortnights of various types of infestations recorded during 1971-1980 at different stations

species in Europe and Africa did not show a definite relationship with fluctuations in sunspot (Uvarov 1931). It may be due to the fact that all species of locusts may not responding to the periodic variations in climate caused by sunspot fluctuations in the same way and at the same time.

Waloff (1960) did not support all 11-year cycle, so it was recommended (WMO Tech. No. 54) to re-examine this relationship. Therefore, we studied the relationship between sunspot fluctuations and locust swarms observed in northwest India.

## 2. Materials and methods

The data on locust activity were taken from the Bulletins of the Directorate of Plant Protection and Quarantine Services of the Food and Agricultural Ministry, Government of India, Faridabad. The past informations on synoptic disturbances causing rainfall in India were collected from *Indian Daily Weather Report* (*IDWR*) and the *Storm Atlas of India* published by India Meteorological Department. The monthly sunspot numbers were taken from the "*Solar-Geophysical Data*" issued by the Environmental Science Services Administration Research Laboratories, Washington, D. C. The stations with sufficient data, namely, Sriganganagar (GGN), Churu (CRU), Bikaner (BKR), Jodhpur (JDP), Jaisalmer (JSM), Barmer (BRM) and Deesa, all from northwest India, were selected for the study. The various types of monthly infestations: egg-layings, hoppers, scattered adults and swarms, at these stations are presented in Fig. 1 as the percentage number of fortnights of infestations during 1971-80. The total number of swarms recorded in each fortnight between January & December and number of swarms recorded in each year, during 1945-80 at these staions are shown in Figs. 2 and 3 respectively.

Since Jaisalmer recorded the highest number of locust activity at all phases of its growth, it was chosen for a detailed study of the relationship between different types of locust activities and various synoptic features causing rainfall in India and sunspot numbers.

To assess the degree of correlation between synoptic disturbances and locust activities, correlation coefficients ($r$) were calculated by simple linear correlation technique using a third generation computer EC-1040 having power software system available at the National Data Centre of India Meteorological Department, Pune.

## 3. Results and discussion

3.1. *Locust activity during* 1971-80 — The highest egg-laying activity was found in June at Bikaner, Churu and Jodhpur, in July at Sriganganagar, and

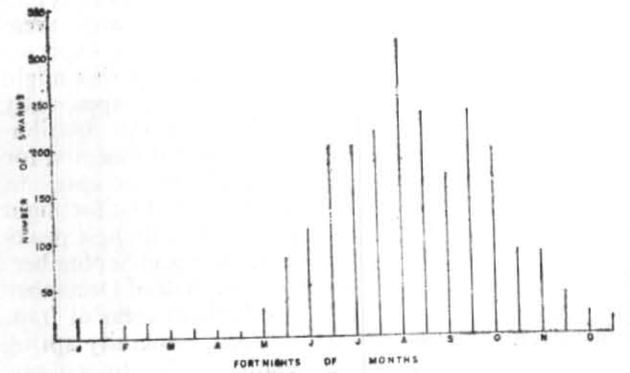


Fig. 2. Total number of swarms during each fortnight of the months for the period 1945-1980 over seven selected stations of northwest India


Fig. 3. Yearly variation of total number of swarms over seven selected stations

in August at Barmer and Jaisalmer (Fig. 1). The chronological order of maximum egg-laying follows the spatial progress of normal monsoon onset with pre-monsoon rains. Generally the maximum hopper activities periods fall one month behind maximum egg-laying period and that of scattered adults are one month behind the maximum hopper activity periods and swarm activities follow no continuity in the

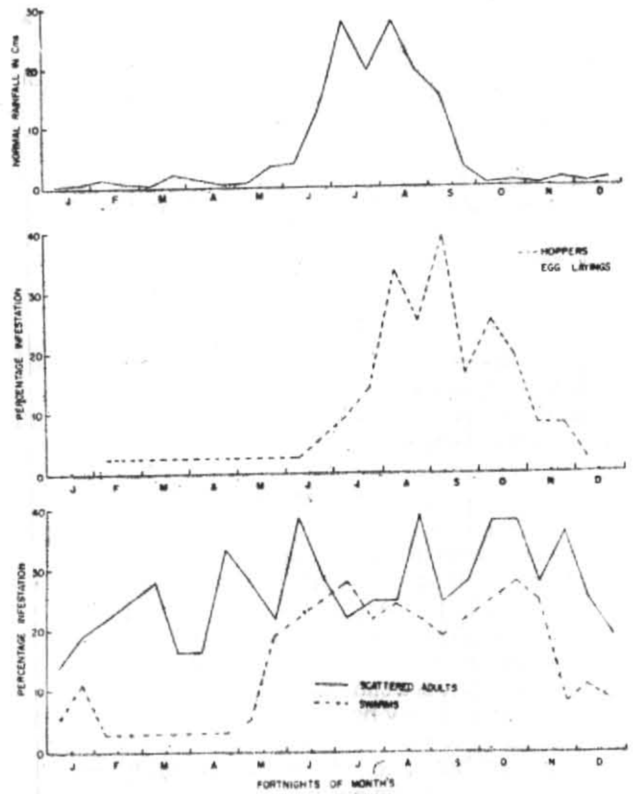


Fig. 4. Fortnightly normals of rainfall and locust activities in different phases during 1945-1980 at Jaisalmer

period with hopper or scattered adults (Fig. 1). It supports the fact that swarms are mostly migrated from neighbouring western countries.

3.2. *Seasonal distribution of swarms and its periodicity* — The peak swarm activity was found in the first fortnight of August with a fall in first fortnight of September and again rise in second fortnight of September (Fig. 2). It's lowest activity was recorded in the second fortnight of April. The rise in activity with time starts from May with a higher rate than its fall after August. The more number of western disturbances and associated induced lows over Rajasthan moving eastward and causing occasional precipitations might have prolonged the influx of swarms from western countries. Westerly and northwesterly winds associated with western disturbances are favourable to bring more swarms. The smallest number of western disturbances and almost no rainfall may be the cause of lowest swarm activity in April whereas more precipitation and favourable westerly/northwesterly winds, availability of sufficient vegetation due to earlier arrival of monsoon in that area, might have caused the peak intensity in August.

The periodical recurrence of lowest infestations in India is generally recognised. In Fig. 3 it is seen that locust swarms were present continuously for a series of years, after which they had disappeared altogether for some time and then reappeared in full strength after longer or shorter interval. The unexpectedness of their onslaughts, make the locusts a great threat to cultivation. This figure clearly shows that there have been six fairly distinct locust cycles covering a period to 5 to 10 years consisting of 2 to 6 years of continuous locust menace and 3 to 4 years of continuous break. Two spells of locust before 1963 were of maximum duration that is 5-6 years. Afterwards longer spells were not observed. It may be due to more precautionary measures to check the swarms. The fluctuations within a period of infestation can be accounted for by variations in rainfall. This point is discussed later in a detailed study of locust swarms at Jaisalmer.

3.3. *Locust activity and rainfall during* 1945-1980 — The fortnightly normal rainfall at Jaisalmer during the year 1945-80 and percentage of locust activities in different phases are plotted in Fig. 4. The association of locust activities in its different phases with rainfall is discussed below.

3.3.1. *Average rainfall* — Rainfall is an essential element to create suitable condition for breeding, hoppers development and adults concentration forming swarms. It is seen that peak of rainfall are in first week of July and August with a dip in the second week of July. After second week of June, there is a sudden increase in rainfall whereas after first week of September there is a sudden fall. Arrival of monsoon and its withdrawal may be the general cause of sudden increase and decrease of rainfall, whereas a general occurrence of break conditions during July may be the cause of 'dip' in the curve.

3.3.2. *Egg-laying* — The sudden increase in egg-laying activity was found in the first week of July, remained constant upto 1st week of August and increased by second week of August and decreased after first week of September. This shows that egg-laying activity was very much parallel with the amount of rainfall. The presence of sufficient moisture in soft and sandy soil of Jaisalmer might be its main cause. Once the soil is sufficiently moist, a dip in rainfall has no effect in its activity and it remains constant till another rise in rainfall which increases the egg-laying. It's correlation coefficient was 0.86, significant at 1% level.

3.3.3. *Hopper* — A sudden increase in hopper emergence starts after second half of July with the highest peak in first fortnight of September and lower peaks in August and October, with a fall in second fortnight of August and September. The lag in first peak of hopper emergence behind rainfall is found to be approximately one month which may be the time lapsed in oviposition and incubation. Other dips in hopper emergence curve may be due to control measures. The correlation between hopper emergence and rainfall was 0.53 significant at 1% level.

3.3.4. *Scattered adults* — The intensity of scattered adults has shown six peaks with the highest in first week of June and second week of August. It shows no association with rainfall indicated by correlation coefficient of .06 which is not significant. The mortality and egg-laying in groups at definite time intervals depending upon the local situations may be the reason for several peaks.

3.3.5. *Swarms* — The major displacements of locust swarms take place with down wind, towards areas of convergence; swarms may in general be expected to collect in the vicinity of such areas and this might provide a mechanism for the close and apparently purposeful association observed between the distribution and movement of swarms and rainfall essential for breeding. The swarm intensity suddenly increases in second week of May, remains higher till first fortnight of November and then falls suddenly. The highest peaks are observed in first fortnight of August and September. Two small humps are also seen in first half of December and second half of January. In the land areas of Iran, Afganistan and Soviet-middle Asia, generally spring breedings take place in association with atmospheric disturbances moving from the west. The matured locusts move towards east with the normal westerly winds during May which may cause sudden increase of swarms in May. In India the main breeding season is during monsoon, with sometimes continuing in winter also. It explains the wide peak in swarm intensity curve from May to middle of November. Two smaller humps in the curve may be due to occassional winter breeding in India. The correlation between swarms and rainfall was 0.56 significant at 1% level.

3.4. *Meteorological disturbances and sunspot number associated with locust activities* — The yearly percentage infestation of egg-layings, hoppers, scattered adults, swarms and the total number of sunspots are depicted in Fig. 5(a) in the form of histograms. An yearly total number of rain causing synoptic disturbances, *viz.*, western disturbances (WD), depression over Bay of Bengal (BBDP), depression over Arabian Sea (ASDP), depression over land (LDDP) and total rainfall at Jaisalmer during the period, are plotted as histogram in Fig. 5(b). The relationship between different phases of locust activities and sunspot and that of different meteorological disturbances are discussed in the following sections.

3.4.1. *Locust phases and sunspots* — As it is clear in Fig. 5(a) the egg-laying activities were more upto 1954, and were negligible afterwards except in 1960, 1962 and 1978. The continuous watch over the area and taking anti-locust measures may be the cause of low egg-laying. Hopper emergence shows the periodicity in recurrence with maximum intensity during 1953-54, 1959, 1971, 1975 and 1978. The continuous yearly activities are noticed for the longest period of 6 years in the period 1950-55 and 1957-62. The variations in the intensity of scattered adults show a periodicity of 3-5 years. The yearly variation of swarm intensity is periodic in nature as observed over all the stations of northwest India in earlier discussion. The continuous occurrences for 1 to 6 years with break of 2 to 3 years are found. The longest continuation of 6 years was observed during 1950 to 1955 and 1959-64. The maximum swarm activities are noticed in the minima of eleven years sunspot cycle.

3.4.2. *Meteorological disturbances and rainfall* — The main meteorological disturbances causing rainfall over India are LDDP, ASDP, BBDP and WD.

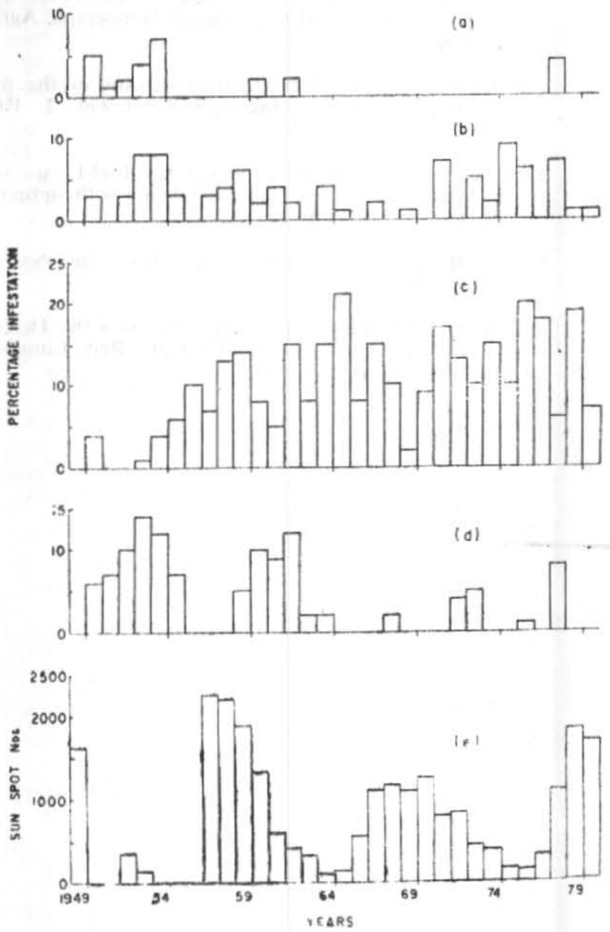


Fig. 5(a). Yearly variations of (a) Egg-layings, (b) Hoppers, (c) Scattered adults, (d) Swarms & (e) Sunspot numbers

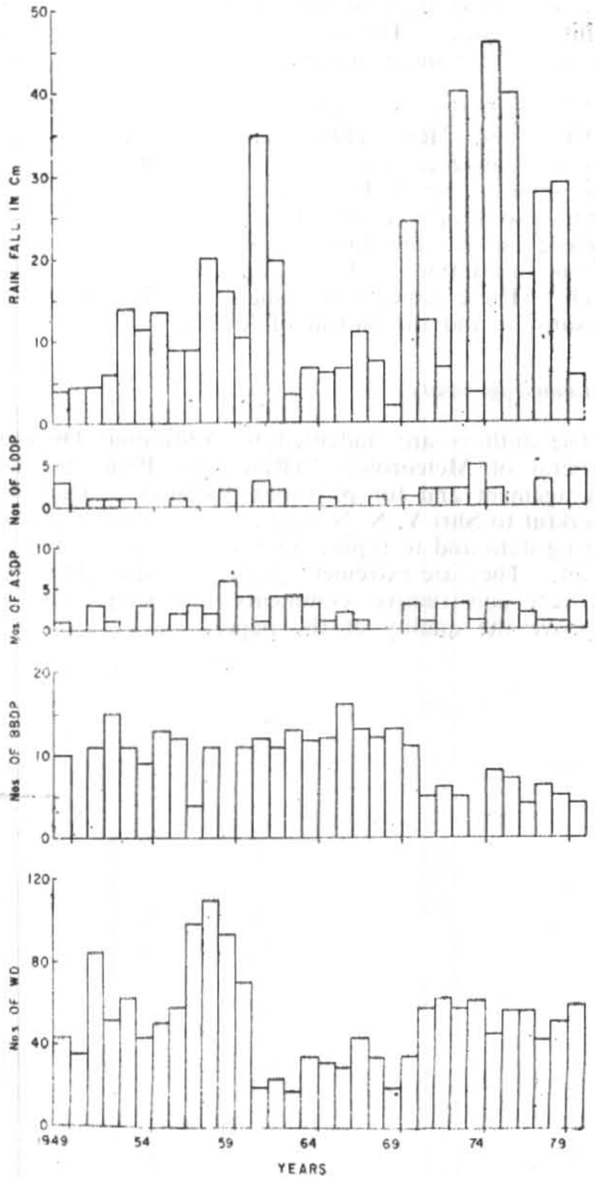


Fig. 5(b). Yearly variations of rainfall at Jaisalmer and other meteorological disturbances causing rainfall during 1945-1980

Their yearly variations, alongwith rainfall at Jaisalmer are shown in Fig. 5(b). It may be seen that the years of maximum frequency of WD, ASDP and LDDP mostly coincide with the years of maximum rainfall at Jaisalmer but that of BBDP shows an opposite trend. It indicates that the main systems causing rainfall over Jaisalmer are WD, ASDP and a few of LDDP. The depressions originated over Bay of Bengal do not give rainfall over that area. The direction of its movement is also westerly to northwesterly, whereas WD and ASDP move eastward or northeastward which can help the incursion of locust swarm over northwest India. To have a quantitative estimate of their degree of association the correlation coefficients ($r$) were calculated between yearly values of activities in different phases and that of meteorological disturbances. It is found that only rainfall has significant correlations of .53 at 1% level in hopper stage and .36 at 5% level with scattered activity. Others have no significant correlations. It is due to combining large periods which might have nullified the individual effect in a certain month. The correlation coefficient between fortnightly values of rainfall during 1945-80 and that of activities in different phases are also calculated. Fortnightly rainfall shows the highest degree of correlation (*viz.*, .86) with egg-laying, hoppers and swarms have correlation of .53 and .56 at 1% level of significance respectively. The scattered activity is not having good correlation. It may be due to the fact of "its control by local situation". A good rainfall creates favourable condition for egg-laying. The production of good vegetation due to rainfall helps growth of hoppers due to availability of food. The wind convergence causing rainfall may form more swarms.

3.5. *Activities in relation to sunspot* — Uichanco (1936) and Rao (1940) suggested that sunspot has a negative correlation with locust fluctuations in Philippines and India respectively. The present study also supports that because $r = -0.37$ was worked out for the numbers of sunspots against the swarm infestation. The value is significant at 5% level. There appears periodicity in the occurrence of sunspot and the swarm of locust.

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