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Short Communication

Relation between desert locust (*Schistocerca gregaria*) incidences and rainfall during southwest monsoon season over West Rajasthan

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Locust are short horned grasshoppers that change their behaviour and appearance switching from solitary lifestyle to gregarious group of bright coloured swarms (adults) and hopper bands (nymphal congregation) causing severe damage to vegetation due to their voracious feeding habit. Desert locust (*Schistocerca gregaria*), Migratory locust (*Locustami gratoria*), Bombay Locust (*Nomadaeris succincta*) and Tree locust (*Anacridium sp.*) are the four species of locust found in India. Desert locust is considered as the most dangerous among all species having invasion area of 30 million sq. km and affects about 64 countries of the world (Cressam and Elliott, 2014). Due to vast area of infestation under varied ecological, geographical and climatological conditions, control of desert locust pest is monitored by Food and Agriculture Organization (FAO) since 1964. FAO has classified the entire area in 5 regions where India along with Pakistan, Iran and Afghanistan came in Southwest Asia Region¹. Desert locust have three stage life cycle (egg, hopper and adult); and two behavioural phases (Solitary and Gregarious phase), the later one capable of devastating crops (Simpson, 1999). Based on degree of infestation, the locust attacks are classified as outbreak, upsurge and plague. *Outbreak*, a situation of marked increase in locust numbers due to concentration is multiplication and gregarization, which unless checked, can lead to the formation of hopper bands and swarms. *Upsurge* is a period which is follows a recessions, marked initially by a very large increase in locust numbers and contemporaneous outbreaks followed by production of two or more successive breeding in the same or neighbouring regions. *Plague* is a period of one or more years of widespread and heavy infestations with majority of infestation occurring as bands or swarms. A major plague exists when two or more regions are affected simultaneously. Eleven desert area districts of west Rajasthan - Alwar, Barmer, Bikaner, Churu, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur, Sikar and Sriganganagar - have listed by Directorate of Plant Protection,

Quarantine and Storage (PPQ&S), Ministry of Agriculture and Farmers Welfare as breeding areas (DPP, 2020).

The recent locust attack (2019-20), considered as one of the severe events of last 60 years, is feared to cause serious economic losses. Regional fluctuation in rainfall have the primary influence on locust numbers (Bennett, 1956). Reduction in locust activity since 1965 is due to rainfall pattern change (Magor *et al.*, 2007). Desert locusts require sufficient rainfall (25 mm a month) as they need moist soil for egg laying and incubation. Summer breeding of Desert Locust occurs in the desert plain along the Indo-Pakistan border. Locusts are present in these areas every year. However, only one generation of breeding occurs during summer with egg laying during June- July, hatching from July to August and start of fledging from September to October (Cressam and Elliott, 2014). Several incidences of locust attacks have been recorded in the past causing huge crop losses (DPP, 2020). Information on yearly locust plagues and upsurges as well as small scale localized breeding have been taken from websites (DPP, 2020; FAO, 2020) and previous research papers (Sharma, 2014). Early onset, late withdrawal and fewer breaks in the monsoon provide congenial environment for second generation of breeding in the area. To analyse this relationship, rainfall data of .25*.25 gridded rainfall data of IMD (1956-2019) of India Meteorological Department (Pai *et al.*, 2014). Daily rainfall data were used to calculate monthly total, monthly normal rainfall (1961-1990) and tercile values. Dates of onset and withdrawal have been taken from papers and Rainfall reports and Monsoon report of IMD (Ali and Loe, 2005; IMD, 2020). Details of 25 incidences (6 outbreaks, 10 upsurges and 7 plagues and 2 small localized infestations) reported in India along with rainfall during southwest monsoon season and duration of the season during the period from 1956 to 2019 have been given in (Table 1).

The average seasonal rainfall of the 11 districts for the

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Table 1: Time series data of Locust attack and SW Monsoon features

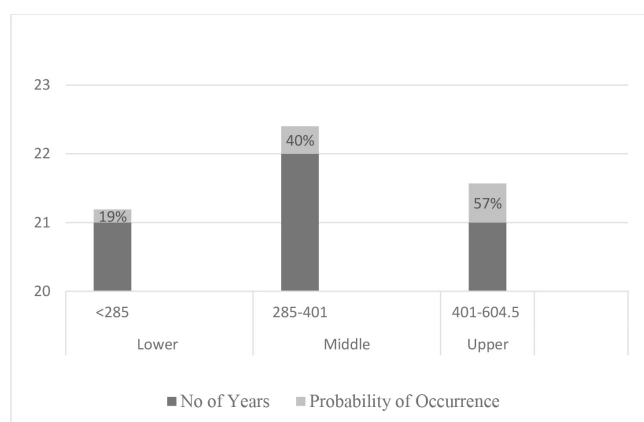
Year	Locust Population	Rainfall (mm)	Date of monsoon onset	Date of monsoon withdrawal	Duration of monsoon season (Days)
1956	Outbreak	401.8	10-Jun	12-Sep	94
1957	---	316.0	11-Jul	11-Sep	62
1958	Plague	346.4	09-Jul	24-Sep	77
1959	Plague	354.6	08-Jul	14-Oct	98
1960	Plague	316.8	29-Jun	04-Sep	67
1961	Plague	409.8	21-Jun	02-Oct	103
1962	Plague	526.4	05-Jul	26-Sep	83
1963	---	257.2	14-Jul	18-Sep	66
1964	Outbreak	443.5	06-Jul	28-Sep	84
1965	---	243.4	14-Jul	18-Sep	66
1966	---	288.8	06-Jul	20-Sep	85
1967	Plague	380.6	02-Jul	21-Sep	81
1968	Plague	201.7	09-Jul	30 Aug	52
1969	---	231.0	15-Jul	17-Sep	64
1970	Upsurge	401.6	03-Jul	29-Sep	88
1971	---	327.1	02-Jul	13-Sep	73
1972	---	240.4	30-Jul	06-Sep	68
1973	Upsurge	465.3	06-Jul	12-Sep	68
1974	Upsurge	231.6	12-Jul	04-Sep	54
1975	Upsurge	604.1	30-Jun	23-Sep	85
1976	Upsurge	473.0	15-Jul	19-Sep	66
1977	---	563.8	30-Jun	23-Sep	76
1978	Upsurge	465.8	03-Jul	11-Sep	70
1979	---	223.8	15-Jul	16-Sep	63
1980	---	278.6	28-Jun	12-Sep	76
1981	---	277.7	10-Jul	03-Sep	55
1982	---	239.8	22 Jul	03-Sep	43
1983	Outbreak	460.6	18 Jul	19-Sep	64
1984	----	279.6	06-Jul	23-Sep	78
1985	----	271.0	14-Jul	11-Sep	59
1986	Outbreak	189.7	24 Jul	17-Sep	55
1987	----	118.7	27 -Jul	12-Sep	47
1988	Upsurge	375.8	01-Jul	12-Sep	73
1989	Upsurge	262.6	02-Jul	04 Oct	94
1990	Upsurge	411.5	01-Jul	28-Sep	89
1991	---	213.8	19-Jul	18- Sep	61
1992	---	442.5	14-Jul	17-Sep	65
1993	Upsurge	351.4	05-Jul	21-Sep	78
1994	---	427.0	30-Jun	19-Sep	81
1995	---	464.8	13-Jul	15-Sep	64
1996	---	458.4	24-Jun	17-Sep	85
1997	Outbreak	337.8	19-Jul	18-Sep	61
1998	---	296.0	30-Jun	28-Sep	90
1999	---	184.7	12-Jul	21-Sep	71
2000	---	265.7	02 Jul	13-Sep	73
2001	---	289.8	03-Jul	10-Sep	69
2002	---	96.7	15-Aug	16-Sep	32
2003	---	425.2	05-Jul	19-Sep	76
2004	----	217.3	02-Jul	16-Sep	62
2005	Small localized breeding	318.1	03-Jul	19-Sep	76
2006	---	344.8	12-Jul	21-Sep	71
2007	---	308.1	12-Jul	30-Sep	80

Table 1: Continue.....

Year	Locust Population	Rainfall (mm)	Date of monsoon onset	Date of monsoon withdrawal	Duration of monsoon season (Days)
2008		400.9	10-Jul	28-Sep	80
2009		206.0	3-Jul	25-Sep	84
2010	Small localized breeding	541.0	6-Jul	27-Sep	83
2011		476.9	9-Jul	21-Sep	74
2012		409.1	11-Jul	24-Sep	75
2013		408.0	17-Jun	9-Sep	84
2014		306.0	17-Jul	17-Sep	62
2015		386.0	26-Jun	9-Sep	75
2016		375.9	5-Jul	15-Sep	72
2017		358.6	4-Jul	30-Sep	88
2018		285.6	10-Jul	29-Sep	81
2019	Outbreak	381.5	18-Jul	9-Oct	83
Normal (based on 1981-2010)		315.0	9 th July (\pm 10)	19 th Sep (\pm 8)	72 Days (\pm 14)

Table 2: Tercile analysis of South West monsoon rainfall over WR

	RF in mm	No of Years	Years of Locust incidence	Probability of Occurrence
Lower Tercile	<285	21	4 (1968,1986, 1989,1974)	19%
Middle Tercile	285-401	22	9 (1958, 1959,1960, 1967,1988,1993, 1997, 2005, 2019)	40%
Upper Tercile	401-604.5	21	12 (1956,1961, 1962, 1964,1970, 1973, 1975,1976, 1978, 1983,1990, 2010)	57%
	>315	>315	36 Years of above normal RF out of 64 years period	58%
Incidences not captured in above normal rainfall		27 Years of below normal RF out of 64 years period	4 (1968, 1974, 1986, 1989) (16 % of total incidence)	14 %

**Fig.1:** Percent contribution of SW monsoon tercile in locust incidence years

period 1981 to 2010 was found to be 315 mm, the average date of onset and withdrawal were 9 July and 19 September respectively and average duration of monsoon season to be 72 days. Time series data of seasonal rainfall were divided into cut off values of Tercile to find the impact of rainfall on incidence of locust (Table 2). Analysis of 64 years monsoon rainfall indicates that 84% of total incidences coincides with the above normal rainfall years. In detailed analysis of RF data it is observed that probability of locust incidence in bottom tercile is 19%, in middle tercile is 40%

% whereas it increases to 58% in upper tercile indicating increase in probability of locust attack increases with increase of rainfall. Southwest monsoon of WR supports the increase in incidence of locust during more than normal rainfall years except 4 cases of total analysis period. Searched literature for listed years indicates that 1968, 1989 and 1974 were plague and upsurge respectively when swarm from spring and winter breeding areas reached to Indo Pakistan border and results in locust attack. In 1986 widespread rainfall in July and august allows breeding to occur till October and infestation also supplemented with adult influx from spring breeding areas (Cressam and Elliott, 2014). Total rainfall during SW monsoon and its temporal distribution seem to have significant impact on the occurrence of pest incidence such as onset and withdrawal date of monsoon. According to FAO, if the monsoon rain commences two week earlier and continue into October then there can be sufficient time for two generation of breeding to take place between June to November which leads to rapid increase in locust number and swarm formation (Cressam and Elliott, 2014). Out of total analysis period, the late monsoon withdrawal years in October viz.1959, 1961, 1989 and 2019 had locust infestation. As In case of 2019, less control operations in Iran and Yemen resulted in the swarms invading the Indo-Pakistan border in June. Further delayed withdrawal of monsoon provided sufficient soil moisture for second generation breeding. Contribution of post monsoon in total rainfall of West Rajasthan is very less but residual soil moisture

after monsoon with less rainfall in post monsoon provides congenial environment for second generation breeding. In detailed analysis of post monsoon season RF data it is observed that probability of locust incidence in bottom tercile is 28%. Lower tercile includes 4 above mentioned exceptional years also, excluding those 4 years reduces the probability to 12% in lower tercile. In middle tercile probability of occurrence is 20 % whereas it increases to 52% in upper tercile indicating that increase of probability of locust attack increases with rainfall. All the incidence years of post monsoon upper tercile range also fell in the upper tercile range of monsoon rainfall indicating that good monsoon rainfall followed by good post monsoon rainfall increases the incidence locust infestation. Analysis of number of rainy days and their relation with incidence years indicates incidences years are more concentrated in the years with more number of rainy days. Hence temporal distribution of rainfall also supports the incidence occurrence.

Monitoring the rainfall amount, onset and withdrawal of monsoon could be used as potential tools to indicate increased infestation of locust attack. Since the locust swarm migration is inter-countries phenomena, watch on spring breeding area population, wind direction and convergence, vegetation status and monitoring of soil moisture status are required to track and control the locust attack.

Conflict of Interest Statement: The author(s) declare(s) that there is no conflict of interest.

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