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Recurrence Frequency and Variability Analysis of Fog Events for Planning and Management of Potato in Eastern U.P. India

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A B S T R A C T

The recurrence frequency of fog events on annual, decadal, seasonal and fortnightly basis of eastern Uttar Pradesh, Faizabad district were made from long period average data of 1986-2015. From 2012 onwards in December and January months the fog frequency increased exponentially. In terms of percentage of fog frequency during second fortnight (1986-2014), 37 % frequency of occurrence of fog above the normal was recorded in November, 48 % in December and 44% in January and in month of February it was 68%.Total 33% fog occurrence was recorded in first decade (1986-1995) 38 % in 2nd decade (1996-2005) i.e. 5% increase as compared to first decade then after decreased to 29% in 3rd decade (2006-2015) hence indicated that fog occurrence was oscillating between 29% to 38%. December and January months were recorded higher days of fog occurrence in each decade. In the decade 1986-95, out of total, 32% fog days occurred in December, and 30% in January. While in 2nd decade (1996-2005) it was 29.5 and 42% in December andJanuary respectively and in 3rd decade it was further increased in December to 36 % but decreased from 42% to 38 % in January. In Monthly variation December and January months were recorded higher days of fog occurrence in each decade.

Introduction

Possible impact of climate change on frequency and severity of weather extremes can have a significant impact on agriculture production, but their effect is often unclear, this may be due to interaction with other factors that affect yield and due to lack of precise definitions of relevant weather extremes (Vanoort, 2012). The Climate variability and weather extremes are principal sources of fluctuations of annual productivity of many crops in arid and semi-arid environments. Of the total annual crop losses in world agriculture, many are due to direct weather and climatic effects such as drought, flash floods, untimely rains, frost, hail, and storm. Temperature and precipitation are the major weather variables that determine the variability of crop yields (Bannayan and Sanjani, 2011). Under the impact of future scenario of climate change and global

warming, the abberent weather and extreme weather events *viz.*, frost, fog, extreme cold and hot weather, hail storm/sleet etc. affect the growth of sensitive rabi crops like potato in India and might be arrested or even reversed, unless effective adaptation measures are evolved for timely intervention. Studies on weather parameters carried out at Central Potato Research Institute Campus, Modipuram in early, main and spring crops for mean leaf hopper population in potato during three different crop seasons, confirmed that early crops planted during September favoured highest development of leaf hoppers followed by main (Oct-Feb) and spring crops (Dec-April) under variable weather conditions. Also a distinct varietal difference was observed in appearance and build-up of leaf hoppers (Sharma and Singh, 2012). Hence disease development was greatly influenced by the weather conditions and intensification occurs at extreme weather condition (Zolfagari *et al.,* 2011). High preparedness, prior knowledge of the timing and magnitude of weather events and climatic anomalies and effective recovery plans will do much to reduce their impact on production levels (Mavi and Tupper, 2004).

Materials and Methods

Faizabad district of eastern U.P. enjoys sub humid climate and received average annual rainfall about 1036 mm. On an average about 85 per cent of the total rainfall is received during monsoon period *i.e.* from June to September, However, occasionally 5 to 7 per cent showers occur during winter season. In the district, normally onset of monsoon begins during third week of June and cessation of monsoon occurs by the end of September or 1st week of October (Tripathi *et al.,* 1998). The aberrant weather and extreme weather events *viz.*, fog, frost, extreme cold and hot weather, hail storm /sleet etc affect the growth of sensitive *rabi* crops like potato in India to the great extent. Hence in order to study the

fog recurrence frequency, the data of eastern U.P./faizabad district from 1986-2015 on daily bases has been collected. The recurrence frequency and events of occurrence of fog were analyzed on annual, decadal, seasonal and fortnightly basis for period 1986-2015 from Agromet observatory data located at N.D. University of Agriculture and Technology, Kumarganj, Faizabad, U.P.

Results and Discussion

The annual and monthly variation of number of days of fog occurrence recorded during1986 -2015 in different years (Table 1) and its variation during crop season (Fig. 1). From table 1, it was revealed that maximum 55 days fog occurred during 1998 followed by 54 days in 1999 and 53 days in 2014. The average number of days of fog events during the recorded period 1986 -2015 was 33.6 or 37 days per year during winter season (Nov to Feb). Fog recurrence during month of January was highest (355 out of 975) followed by December 315, February179 and November 126. The maximum frequency of fog per year 12.5 was recorded in month of January followed by December 10.8 and February 6.17.respectively.

Annual variability of fog days was observed that the annual variation of fog incidence during winter/rabi crop season possess the polynomial cycle of order 3 with increasing amplitude. The average number of fog days in a year *i.e.* normal days of fog occurrence was 32.86 or 37 days per year in the area. From 2012 onwards fog frequency rapidly increased exponentially. This was the alarming situation for the crops sensitive to the fog, and high relative humidity. More number of occurrences of fog in a season reduced the duration of bright sunshine hours and increased the relative humidity. This ultimately not only affects the crop growth and development but also creates the

congenial environment to invite for incidence of insect- pest and diseases.

Variation of fog during peak period of its occurrence in January and December (Figs. 2 and 3) both possess the polynomial cycle of order 3 with increasing amplitude. On the basis of long term data for the period 1986-2015, the average number of fog days in the month of January *i.e.* normal days of fog occurrence was 12.24 days and in month of December it was 10.86 or 11 days in the area. From 2012 onwards in both months (December and January) the fog frequency rapidly increased exponentially.

This is the peak period for occurrence of late blight in potato, powdery mildew in pea crop etc. More number of fog days during January increases the relative humidity and shortened the bright sunshine hour and adversely affect the flower initiation and number of flower formation in pigeon pea. Hence intensification of crop protection measures is required.

Fortnightly variation (Table 2) of fog during November to February (1986-2014) revealed that the frequency of occurrence of fog events in first fort night during month of November was 10 days above the normal (2.13) while during the month of December it was 13 days but in January it was same as that of December *i.e.*13 days, and in month of February fog events was 14 days above the normal. In second fort night during month of November (1986-2014) 11 days fog event was observed above the normal (2.20) while during the month of December it was 14 days above the normal, month of January 13 days, and month of February it was quite high 20 days average fog events above the normal were recorded. In terms of percentage of fog during first fort night (1986-2014), 34 % frequency of occurrence of fog above the normal was recorded in November, 44 % in December and same in January 44% and

month of February it was quite high as compare to November (48%). Similarly in terms of percentage of fog during second fort night (1986-2014), 37 % frequency of occurrence of fog above the normal was recorded in November, 48 % in December and 44% in January and month of February it was 68%.

The characteristic feature of the variability of fog days during peak period of its occurrence in the Month of December and January (Figs. 4 and 5) indicate annual variation of fog incidence during January and December both possess the polynomial cycle of order 3 with increasing amplitude.

On the basis of long term data for the period 1986-2015, the average number of fog days in the month of January in first fortnight *i.e.* normal days of fog occurrence was 6.5 days and in second fortnight it was 5.6 days in the area. From 2012 onwards in both fortnights, the fog frequency rapidly increased exponentially.

The decadal variation of fog occurrence on monthly basis has been depicted in table 3 and 5 for period 1986-1995, 1996-2005 and 2006-2015 respectively. From the table, it was observed that total number of fog days during this decade was 324 or 32 days once in a year.

Again December month was reported to possess maximum number days of fog days (103) followed by January 97 days, February 81days and November 37 days only. Maximum number (49 days) fog occurred during 1987 followed by 1994 (41 days) and 1990 (33 days) in each year. As far as frequency of fog occurrence is concerned, December month possess highest frequency of 10.3 days / year followed by 9.7 day in January, 8.1 day in February. This showed that December and January are at par for fog occurrence the area during this decade.

Table.1 Annual and monthly variation of number of days of fog occurrence

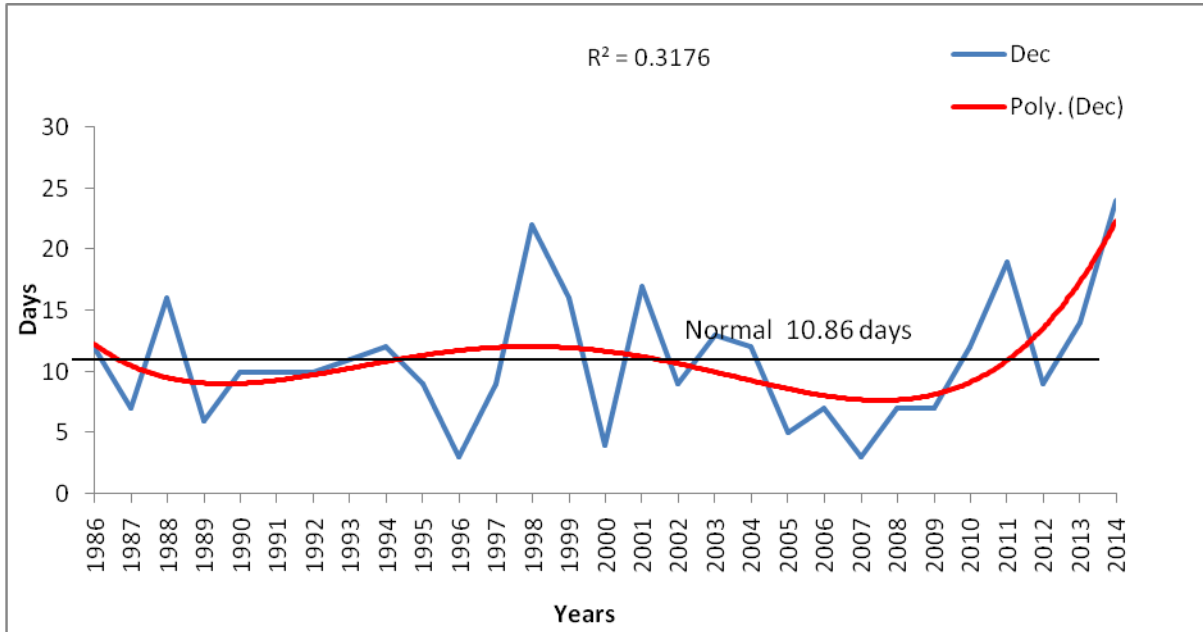|	Months				
years	NOV	DEC	JAN	FEB	TOTAL
1986	2	12	6	11	31
1987	4	7	27	11	49
1988	0	16	0	4	20
1989	7	6	8	9	30
1990	7	10	0	16	33
1991	4	10	6	6	26
1992	4	10	10	9	33
1993	4	11	11	3	29
1994	4	12	16	9	41
1995	7	9	13	3	32
1996	1	3	9	6	19
1997	11	9	15	2	37
1998	9	22	18	6	55
1999	3	16	22	13	54
2000	2	4	18	14	38
2001	2	17	10	2	31
2002	12	9	15	6	42
2003	0	13	30	8	51
2004	3	12	8	1	24
2005	0	5	12	5	22
2006	9	7	3	3	22
2007	0	3	3	11	17
2008	0	7	8	4	19
2009	6	7	12	0	25
2010	9	12	6	4	31
2011	8	19	17	3	47
2012	2	9	10	5	26
2013	3	14	18	3	38
2014	3	24	24	2	53
Total	126	315	355	179	975

Table.2 Fortnightly variation of fog during November to February (1986-2014)

| YEAR	Fortnight	NOV	DEC	JAN	FEB	Total Fortnight	Monthly Fortnight
1986	FF-	1	2	3	11	17	31
	SF-	1	10	3	0	14	
1987	FF-	3	4	13	4	24	49
	SF-	1	3	14	7	25	
1988	FF-	0	8	0	2	10	20
	SF-	0	8	0	2	10	
1989	FF-	5	0	8	8	21	30
	SF-	2	6	0	1	09	
1990	FF-	1	10	0	6	17	33
	SF-	6	0	0	10	16	
1991	FF-	1	0	1	1	03	26
	SF-	3	10	5	5	23	
1992	FF-	2	6	3	5	16	33
	SF-	2	4	7	4	17	
1993	FF-	3	6	2	0	11	29
	SF-	1	5	9	3	18	
1994	FF-	4	7	9	6	26	41
	SF-	0	5	7	3	15	
1995	FF-	4	0	12	2	18	32
	SF-	3	9	1	1	14	
1996	FF-	1	0	7	5	13	19
	SF-	0	3	2	1	06	
1997	FF-	4	0	9	1	14	37
	SF-	7	9	6	1	23	
1998	FF-	4	7	15	2	28	55
	SF-	5	15	3	4	27	
1999	FF-	0	3	15	10	28	54
	SF-	3	13	7	3	26	
2000	FF-	1	1	4	12	18	38
	SF-	1	3	14	2	20	
2001	FF-	2	7	7	1	17	31
	SF-	0	10	3	1	14	
2002	FF-	2	0	6	6	14	42
	SF-	10	9	9	0	28	
2003	FF-	0	3	14	4	21	51
	SF-	0	10	16	4	30	
2004	FF-	0	0	6	1	07	24
	SF-	3	12	2	0	17	
2005	FF-	0	1	3	2	06	22
	SF-	0	4	9	3	16	
2006	FF-	9	3	0	3	15	22
	SF-	0	4	3	0	07	
2007	FF-	0	1	1	8	10	17
	SF-	0	2	2	3	07	
2008	FF-	0	5	1	2	08	19
	SF-	0	2	7	2	11	
2009	FF-	2	1	8	0	11	25
	SF-	4	6	4	0	14	
2010	FF-	4	5	4	4	17	31
	SF-	5	7	2	0	14	
2011	FF-	5	11	14	2	32	47
	SF-	3	8	3	1	15	
2012	FF-	1	2	8	5	16	26
	SF-	1	7	2	0	10	
2013	FF-	1	6	6	1	14	38
	SF-	2	8	12	2	24	
2014	FF-	2	10	12	1	25	53
	SF-	1	14	12	1	28	
Total	FF	**62**	**109**	**191**	**115**	**477**	**975**
	SF	**64**	**206**	**164**	**64**	**498**	
	FF	**2.13**	**3.75**	**6.5**	**3.9**	**16.44**	**33.62**
Normal	SF	**2.20**	**7.10**	**5.6**	**2.20**	**17.17**	

Table.3 Monthly variation of frequency percentage of fog in first and second
Fortnight, during (1986-2014)

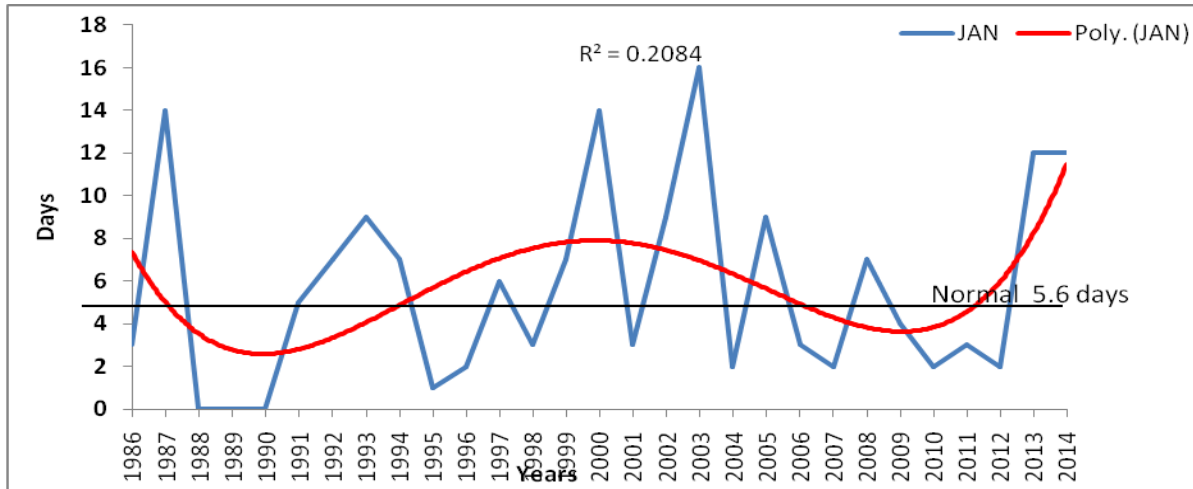| Months				
Fortnight	**November**	**December**	**January**	**February**
First	10(34)	13(44)	13(44)	14(48)
Second	11(37)	14(48)	13(44)	20(68)

Fig.1 Annual variation of fog during crop season

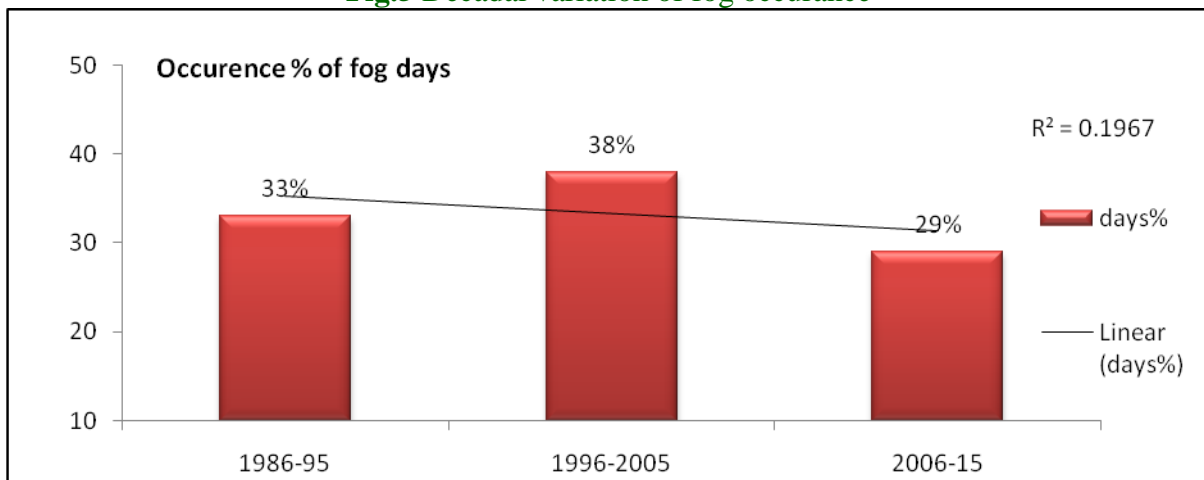

Fig.2 Variation of fog during peak period of December
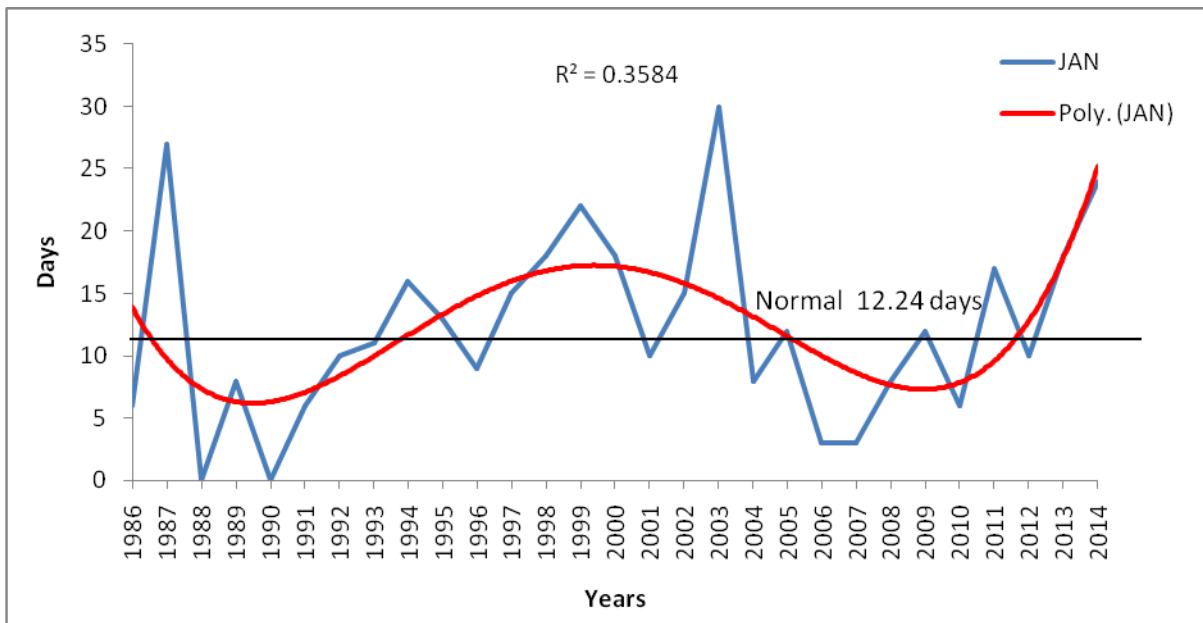
Fig.3 Fog during month of January (Second fortnight) 1986-2014

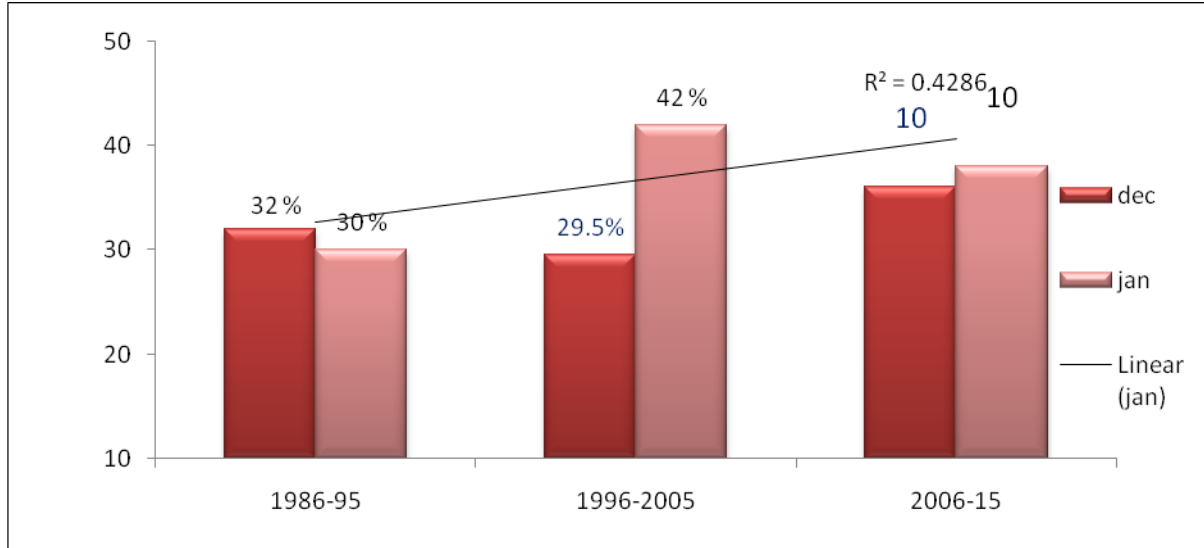**Fig.4** Fog during month of January (First fortnight) 1986-2014
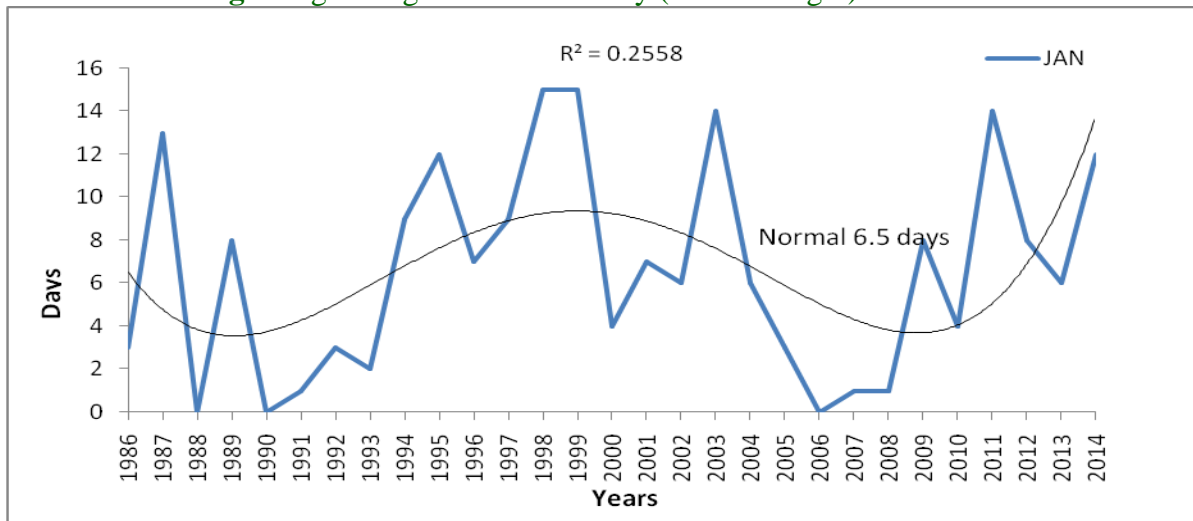
Fig.5 Decadal variation of fog occurance

Fig.6 Monthly occurrenceof fog days (%) during December and January in decade

The decadal variation of the fog occurrence has been shown in Table.3 for period 1986-2014. From table it was observed that total number of fog during this decade was 373 *i.e.* 37.7 or 38 day once in a year, contained more number as compare to previous decade (1986-95)*i.e.*324 days. Again January month was reported to possess maximum number of fog days 157 followed by December 110 days, February 63 and November 43 days respectively, Maximum number (55) of fog days occurred during 1998, followed by 1999 (54) days and 2003 (51) days. From the observation of fog occurrence data of both decade it was recorded that the fog frequency during this decade increased to 373 from 324 as compared to previous decade (1986-95) *i.e.* 15% increase. Similarly fog increment of 6% was reported in January month followed by December 7% and November 2%. But 22% fog frequency reduced during February in this decade as compared to previous decade. This showed that fog occurrence shifted from February to January and December, affecting the crops at vegetative stage of *rabi* crops.

The decadal variation of the fog occurrence has been shown in Table 2for period 2006-2015. From table it was observed that total number of fog days during this decade was 284 *i.e.* 28.4 or 29days once in a year. Again January month was reported to possess maximum number of fog days (107) followed by December 102 days, November 40 days, and February 35 days. Maximum number of fog days was 53 days during 2014 followed by 2011(47) days and 2013(38) days during this decade. During November, December, January and February, all months, the number of fog days was considerably reduced in this decade as compared to previous decade (1996-2005).

In addition, the decadal and monthly variability analysis of fog occurrence as shown in figure 6 which revealed that out of total days of fog occurrence 33% fog days occurred in first decade (1986-1995), 38 % in 2nd decade (1996-2005) *i.e.* 5% increase in this decade as compared to first decade then after decreased to 29% in 3rd decade (2006-2015). This clearly indicated that fog occurrence was oscillating between 29% and 38% *i.e.* within the range of 9% between 1996 and 2015 in the area.

Monthly variation as shown in figure 7 revealed that December and January months

were recorded higher days of fog occurrence in each decade including reporting period of 1986-2015. In the decade 1986-95, out of total 32% fog days occurred in December, 30% in January fog days were recorded. While in 2nd decade (1996-2005) it was 29.5 and 42% in December and January respectively and in 3rd decade it was further increased in December to 36 % but decreased from 42% to 38 % in January.

From the above study, it may be finally concluded that fog frequency both in terms of number of events of fog days and fog frequency was increased. December and January were peak months for maximum fog occurrence in past two decade but in recent decade (2006-2015) fog occurrence in February month was appeared in increasing trend. This ultimately affected the fog sensitive *rabi* crops specially pulses, oil seeds and potato etc. Hence, crop planning, management and remedial measures to combat the adverbs effect of fog is necessarily required.

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