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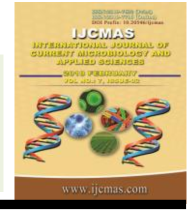

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Impact of Climate Variability on Seed Yield of Onion in Mid Hills of Himachal Pradesh, India

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ABSTRACT

Keywords

Climatic variability, Onion (*Allium cepa* L.), Seed yield

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Present investigation was conducted at Dr. YS Parmar University of Horticulture and Forestry, Nauni (HP) to study the effect of changing climatic conditions on seed yield of onion (*Allium cepa* L.) in mid hills of Himachal Pradesh. The meteorological data (30 years) and onion seed yield data (26 years) were collected; correlation and regression analysis between various weather parameters (temperature, rainfall and relative humidity) and onion seed productivity was done for productivity trend analysis. Weather based crop yield forecast model equation was developed and crop yield was predicted with maximum accuracy of 69 per cent. The trend analysis revealed that onion seed productivity over the last 26 years showed a fluctuating pattern with an overall decreasing trend at the rate of 2.58 kg ha^{-1} per year. Climatic variability analysis indicated an increase in average temperature (0.60°C and 0.46°C) and decrease in total rainfall (57.02 mm and 183.14 mm) during 1995-2004 (decade-1) and 2005-2014 (decade-2), respectively over the baseline (1985-1994). Whereas, relative humidity (RH) showed an increase of 0.03% during first decade and decrease of 3.39% during second decade over the baseline. Thus it can be concluded that changing climatic conditions in mid hills of Himachal Pradesh negatively affected the seed production of onion.

Introduction

Climate change has been become global brainstorming topic as well as major challenge to face especially in agriculture industry. In the next century, the global temperature could increase up to 4.8°C (IPCC, 2013) and if it rise by 2°C or more the production of the world's major crops such as wheat, rice and maize will be hampered (IPCC, 2014). Over the last century, the global mean surface temperature has increased by 0.6°C (Kumar *et al.,* 2009). Though, the impact of climate change is not distributed evenly across the world (Chand, 2009). Globally, the impact of climate change on agriculture sector has become a matter of thinking in food security point of view because it can cause significant crop failures, shortage of yields, reduction in quality and increasing pest and disease problems (Ayyogari *et al.,* 2014).

Similarly, in North West Himalayas the climate is also changing with time and it has shown significant effects on the prevailing agriculture. The winter average temperature of the North West Himalayas followed an increasing trend (Dimri and Kumar, 2008). Cool season vegetable could be good indicator of climate change. Since onion is cool season vegetable crop and they can be more adversely affected by temperature extremes than some warm season crops (McKoewn *et al.*, 2004). Therefore onion was chosen as an indicator crop. Among the various factors behind low seed productivity changing climatic conditions holds prime position. Non availability of the adequate quality seed is another factor which negatively affects the productivity and quality of seed also dependent on the prevailing weather.

There are different problems in North West Himalayan regions in onion seed production due to changing pattern in different climatic components such as extreme winters during vegetative growth or bulb development, high temperature during bolting and seed filling, rains during the flowering period, seed setting and maturity causes shattering and also, the climatic changes can enhance the changes in distribution and effectiveness of the pests and diseases (thrips, downy mildew, purple blotch) of the crop.

In onion seed production, it requires cool weather prior to and during early growth of seed stalk (Hazara and Som, 2009). The rising temperature during seed stalk growth period can affect it adversely and ultimately seed yield will be affected. Dry conditions reduce the occurrence of leaf diseases such as leaf blight (Msuya *et al.*, 2005). Moreover, early rains during stalk development and flowering can harbour different diseases due to humid conditions. These all above mentioned factors reduces the seed quality as well as yield. Therefore the present study was planned to know the effect of different weather components on the seed yield of onion.

Materials and Methods

The present study was conducted during the year 2014-15 at Khaltoo Experimental Farm, Department of seed Science and Technology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh); located at an altitude of 1040 meters above mean sea level with latitude of 30^{o}51'07.17" N and longitude of 77^{o}10'56.63" E in the mid-hill zone of Himachal Pradesh. The weather data (average monthly rainfall, maximum and temperature and relative humidity) for the period 1985-2014 was procured from Department of Environmental Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni. Climate of the area is generally sub-temperate and semi-humid characterized by cold winters. The annual average maximum temperature varies from 17.72°C in January to 31.50°C in May, whereas the annual average minimum temperature ranges from 19.96°C in July to as low as 2.23°C in January. The average annual total rainfall recorded was 1156.19 mm.

Variations in rainfall, maximum, minimum and average temperature and relative humidity were studied and analysed month wise as well as decadal for last three decades. The period 1985 to 1994 was taken as baseline and compared with decade 1995 to 2004 (decade-1) and 2005 to 2014 (decade-2) for variations (increase or decrease) over baseline. Significant effect of dependent variables (weather parameters) on productivity was calculated using correlation analysis and backward regression. The final equation from regression analysis was used to predict the yield. Root mean square error was then computed to calculate error in the prediction by using formula:

RMSE = $\sqrt{\Sigma (\text{Actual Yield-Predicted Yield})^2 / \text{Total number of observations}}$

Results and Discussion

Monthly variations in maximum temperature (°C)

Data from the Table 1 shows prominent increase in maximum temperature over all the months except June during both the decades (1994-2004 and 2005-2014). In the present study highest increase of 2.39°C and 2.60°C in the month of December during both the decades 1995 to 2004 and 2005 to 2014 over the baseline. However, maximum variations of 11.97 per cent in maximum temperature were recorded in the month of January. This may be attributed to low precipitation during the winter months.

In Kullu Valley highest increase in average maximum temperature (2.37°C) in the month of April during the period 1963-72 to 1995-2004 was recorded (Kumar *et al.,* 2009). While, in another study March month showed highest increase during 1995-2004 and 2005-2014 over the base line (1985-1994) at Kullu and Shimla (Chand, 2016).

Monthly variations in minimum temperature (°C)

It is evident from the Table 1 that during 1995-2004 the monthly minimum temperature has been increased in all the months except March. During 2005 to 2014, the mean monthly minimum temperature increased by 0.29°C, 0.24°C and 0.15°C, respectively in the months of February, May and July. During decade-1, maximum increase (0.58°C) was observed in month of May and during decade-2 it was maximum (0.29°C) in the month of February over the baseline (1985 to 1994). This increase can also be attributed to the less rainfall in the respective months. The maximum variations of 61.95 per cent in minimum temperature were recorded during January month. In a study decrease in mean monthly minimum temperature over the base line (1985-1994) in most of the months during 2005-2014 at 2000-2500 m amsl (Shimla) was observed (Chand, 2016). Similarly in Kull valley highest increase in average monthly minimum temperature (2.3°C) in the month of July during (1962-2004) was recorded (Kumar *et al.,* 2009).

Monthly variations in average temperature (°C)

Perusal of data in Table 1 revealed that there is prominent increase in average monthly temperature in all the months except June during both the decades (1995 to 2004 and 2005 to 2014). The maximum increase of 1.28°C and 0.79°C was observed in the month of December during both the decade over the baseline. The less precipitation in the months of November and December might be the reason behind increase in average temperature. However, maximum variations (14.96%) in the average monthly temperature were recorded in the month of January.

The findings are somewhat in agreement with a study in which an increase in average monthly temperature in all the months during 2001-2010 over the base line (1984-1990) in Sirmour (HP) was observed (Joshi, 2011). The increase in temperature during the winter months negatively affects the vernalization phenomenon and vernalization is important for bolting in onion.

Decadal variations in maximum, minimum and average temperature (°C)

The data presented in Table 2 revealed that decadal maximum temperature showed an increasing trend as 24.69°C < 25.63°C < 25.93°C during the period 1985 to 1994, 1995 to 2004 and 2005 to 2014, respectively. The maximum temperature showed an increase of 0.94°C and 1.24°C over the base line during the period of 1995 to 2004 and 2005 to 2014, respectively. The maximum temperature showed variations of 3.65 per cent during the last thirty years (1985-2014). In Kullu (HP) an increase of 1°C in average maximum temperature was recorded during 1990s compared to 1980s (Negi *et al.,* 2012). In Himachal Pradesh, during 1951-2010 the annual mean maximum temperature was increased at the rate of 0.06°C (Rathore *et al.*, 2013).

The data from the Table 2 showed that minimum temperature during the period 1985 to 1994, 1995 to 2004 and 2005 to 2014 was 11.60°C, 11.85°C and 11.28°C, respectively.

Present study revealed that decadal minimum temperature increased by 0.25°C during decade-1 (1995 to 2004), while it decreased by 0.32°C during decade-2 (2004 and 2005) over the base line.

The minimum temperature showed variations of 7.79 per cent over the period of thirty year. In another study, an increase in annual minimum (2.75°C) during the period of 1963-2008 was recorded (Meena and Kumar, 2008). Whereas decreases in annual mean minimum temperature at the rate 0.01°C was observed in Himachal Pradesh during 1951-2010 (Rathore *et al.*, 2013).

Perusal of data in Table 2 showed that decadal average temperature at selected study area was 18.14°C, 18.74°C and 18.61°C, during the period of 1985 to 1994, 1995 to 2004 and 2005 to 2014, respectively. It increased by 0.60°C and 0.46°C during decade-1 and decade-2 over the baseline. It showed variations of 3.68 per cent over the thirty years. The findings are somewhat in agreement with a study where an increasing trend during last three decades (1985-2014) at 2000-2500 m amsl (Shimla) with the variation of 5.59 per cent was recorded (Chand, 2016).

Monthly variations in rainfall (mm)

Scrutiny of data in Table 3 revealed that maximum decrease in total monthly rainfall i.e. 74.46 mm and 56.70 mm was observed in the month of July, whereas maximum increase (68.94 mm and 23.10 mm) was in the month June during both the decades (1995-2004 and 2005-2014) over the base line. However, maximum variations of 179.84 per cent in rainfall were observed during October month.

The results are in conformity with a report in which an increasing trend in June rainfall of Himachal Pradesh during 1951-2010 was found (Rathore *et al.,* 2013).

From the present study it is cleared that there is decrease in rainfall in winters and spring season which adversely hamper the vegetative and reproductive growth of onion during seed production. In another report a decrease in rainfall during winters and spring seasons during 2001-2011 was recorded in sub temperate regions of Himachal Pradesh (Bhardwaj and Sharma, 2013).

Reduction in the rainfall during the seed fill months i.e. March and April may negatively affect the physiological development in seeds and also sometimes may cause the ovule abortion or unfilled grain.

Decadal variations in rainfall (mm)

The data presented in Table 4 revealed that decadal rainfall showed a decreasing trend as 1236.24 mm > 1179.22 mm > 1053.10 mm during the period 1985 to 1994, 1995 to 2004 and 2005 to 2014, respectively.

Table.1 Monthly decadal variations in maximum, minimum and average temperature (°C)

Time Period	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Maximum Temperature (°C)											
1985-1994 (Base Line)	16.66	18.12	22.06	27.05	30.78	31.58	28.48	27.85	27.54	25.85	21.97	18.33
1995-2004 (Decade-1)	17.93	19.64	23.66	28.64	31.88	30.68	28.66	27.66	28.11	26.49	23.51	20.72
2005-2014 (Decade-2)	18.58	19.37	24.57	28.39	31.84	31.56	28.55	28.21	28.1	27.17	23.91	20.93
Mean	**17.72**	**19.04**	**23.43**	**28.03**	**31.50**	**31.27**	**28.56**	**27.91**	**27.92**	**26.50**	**23.13**	**19.99**
SD	2.12	1.93	2.19	2.04	1.55	1.81	1.31	1.10	1.18	1.47	1.40	2.09
CV (%)	11.97	10.11	9.33	7.27	4.92	5.78	4.59	3.94	4.22	5.55	6.05	10.47
Variations over the base line												
Decade-1	1.27	1.52	1.60	1.59	1.10	-0.90	0.18	-0.19	0.57	0.64	1.54	2.39
Decade-2	1.92	1.25	2.51	1.34	1.06	-0.02	0.07	0.36	0.56	1.32	1.94	2.60
Time Period	**Minimum Temperature (°C)**											
1985-1994 (Base Line)	2.36	4.15	9.12	12.52	16.16	18.85	19.72	19.42	16.80	10.79	6.13	3.17
1995-2004 (Decade-1)	2.44	4.48	8.53	12.91	16.74	18.98	20.29	19.88	17.14	11.14	6.37	3.33
2005-2014 (Decade-2)	1.89	4.44	8.16	12.38	16.4	18.49	19.87	19.4	16.52	10.27	5.4	2.15
Mean	**2.23**	**4.36**	**8.60**	**12.60**	**16.43**	**18.77**	**19.96**	**19.57**	**16.82**	**10.73**	**5.97**	**2.88**
SD	1.38	1.46	2.27	1.62	1.58	1.42	1.27	1.39	1.52	1.53	1.44	1.26
CV (%)	61.95	33.50	26.40	12.85	9.62	7.58	6.34	7.10	9.02	14.29	24.11	43.53
Variations over the base line												
Decade-1	0.08	0.33	-0.59	0.39	0.58	0.13	0.57	0.46	0.34	0.35	0.24	0.16
Decade-2	-0.47	0.29	-0.96	-0.14	0.24	-0.36	0.15	-0.02	-0.28	-0.52	-0.73	-1.02
Time Period	**Average Temperature (°C)**											
1985-1994 (Base Line)	9.51	11.14	15.59	19.79	23.47	25.22	24.10	23.64	22.17	18.32	14.05	10.75
1995-2004 (Decade-1)	10.19	12.06	16.10	20.78	24.31	24.83	24.48	23.77	22.63	18.82	14.94	12.03
2005-2014 (Decade-2)	10.24	11.91	16.37	20.39	24.12	25.03	24.21	23.81	22.31	18.72	14.66	11.54
Mean	**9.98**	**11.70**	**16.02**	**20.32**	**23.97**	**25.02**	**24.26**	**23.74**	**22.37**	**18.62**	**14.55**	**11.44**
SD	1.44	1.33	1.91	1.57	1.25	1.33	1.09	1.03	1.09	1.22	1.00	1.14
CV (%)	14.46	11.39	11.93	7.72	5.20	5.31	4.48	4.34	4.86	6.53	6.87	9.93
Variations over the base line												
Decade-1	0.67	0.92	0.51	0.99	0.84	-0.38	0.38	0.13	0.45	0.50	0.89	1.28
Decade-2	0.72	0.77	0.78	0.60	0.65	-0.19	0.11	0.17	0.14	0.40	0.60	0.79

Table.2 Decadal variations in maximum, minimum and average temperature (°C)

Time Period	Maximum Temperature (°C)	Minimum Temperature (°C)	Average Temperature (°C)
1985-1994 (Base Line)	24.69	11.60	18.14
1995-2004 (Decade-1)	25.63	11.85	18.74
2005-2014 (Decade-2)	25.93	11.28	18.61
Mean	**25.42**	**11.58**	**18.50**
SD	0.93	0.90	0.68
CV (%)	3.65	7.79	3.68
Variations over the base line			
Decade-1	0.94	0.25	0.60
Decade-2	1.24	-0.32	0.46

Table.3 Month wise decadal variations in total rainfall (mm)

Time Period	Month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1985-1994 (Base Line)	60.33	67.65	72.34	31.18	80.29	100.46	318.30	267.62	133.48	27.62	13.75	63.22
1995-2004 (Decade-1)	60.91	66.2	60.83	50.08	65.41	169.4	243.84	266.11	127.84	45.72	7.26	15.62
2005-2014 (Decade-2)	47.84	89.49	62.92	25.59	41.55	123.56	261.6	182.46	170.63	14.75	6.94	25.77
Mean	**56.36**	**74.45**	**65.36**	**35.62**	**62.42**	**131.14**	**274.58**	**238.73**	**143.98**	**29.36**	**9.32**	**34.87**
SD	39.37	56.29	50.01	30.30	62.34	83.92	198.32	125.23	110.85	52.81	16.63	47.00
CV (%)	69.85	75.62	76.51	85.06	99.87	63.99	72.23	52.46	76.99	179.84	178.47	134.79
Variations over the base line												
Decade-1	0.58	-1.45	-11.51	18.90	-14.88	68.94	-74.46	-1.51	-5.64	18.10	-6.49	-47.60
Decade-2	-12.49	21.84	-9.42	-5.59	-38.74	23.10	-56.70	-85.16	37.15	-12.87	-6.81	-37.45

Table.4 Decadal variations in total rainfall (mm)

Time Period	Rainfall (mm)
1985-1994 (Base Line)	1236.24
1995-2004 (Decade-1)	1179.22
2005-2014 (Decade-2)	1053.10
Mean	**1156.19**
SD	338.02
CV (%)	29.24
Variations over the base line	
Decade-1	-57.02
Decade-2	-183.14

Table.5 Month wise decadal variations in relative humidity (%)

Time Period	Month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1985-1994 (Base Line)	61.25	59.99	55.83	48.62	50.08	60.85	79.95	83.51	75.19	59.06	58.69	59.93
1995-2004 (Decade-1)	60.28	61.58	52.36	48.56	45.28	64.29	79.61	83.00	76.45	63.02	61.52	57.37
2005-2014 (Decade-2)	56.80	58.35	50.90	44.90	46.50	54.35	76.40	79.80	74.35	60.00	52.75	52.35
Mean	**59.44**	**59.97**	**53.03**	**47.36**	**47.29**	**59.83**	**78.65**	**82.10**	**75.33**	**60.69**	**57.65**	**56.55**
SD	7.01	9.58	8.23	9.59	9.08	11.51	5.13	4.04	7.10	6.64	8.96	7.41
CV (%)	11.80	15.98	15.51	20.24	19.20	19.24	6.52	4.93	9.43	10.93	15.55	13.10
Variations over the base line												
Decade-1	-0.97	1.59	-3.47	-0.06	-4.80	3.44	-0.34	-0.51	1.26	3.96	2.83	-2.56
Decade-2	-4.45	-1.64	-4.93	-3.72	-3.58	-6.50	-3.55	-3.71	-0.84	0.94	-5.94	-7.58

Table.6 Decadal variations in relative humidity (%)

Time Period	Relative Humidity (%)
1985-1994 (Base Line)	62.75
1995-2004 (Decade-1)	62.78
2005-2014 (Decade-2)	58.95
Mean	**61.49**
SD	3.90
CV (%)	6.35
Variations over the base line	
Decade-1	0.03
Decade-2	-3.79

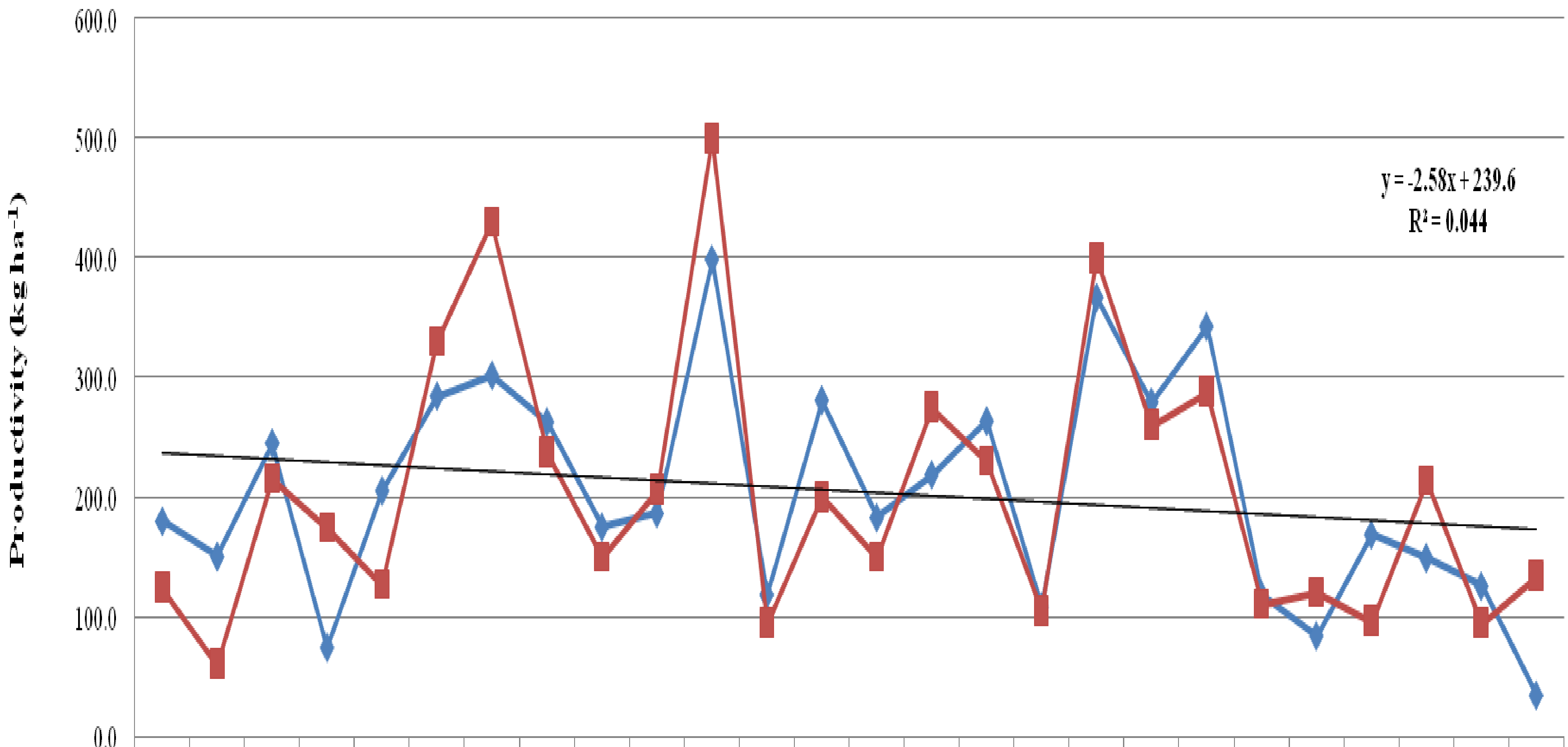
Table.7 Correlation analysis between onion seed productivity and weather parameters

Weather Parameters	Productivity
Maximum Temperature	
Maximum Temperature of cropping season (°C)	-0.1718
Maximum Temperature October (°C)	-0.4213*
Maximum Temperature November (°C)	-0.1263
Maximum Temperature December (°C)	-0.0570
Maximum Temperature January (°C)	0.1366
Maximum Temperature February (°C)	-0.2274
Maximum Temperature March (°C)	-0.3050
Maximum Temperature April (°C)	-0.1316
Maximum Temperature May (°C)	0.2699
Minimum Temperature	
Minimum Temperature of cropping season (°C)	0.1523
Minimum Temperature October (°C)	-0.0043
Minimum Temperature November (°C)	0.3780
Minimum Temperature December (°C)	0.2100
Minimum Temperature January (°C)	0.1954
Minimum Temperature February (°C)	0.3210
Minimum Temperature March (°C)	-0.1088
Minimum Temperature April (°C)	-0.3066
Minimum Temperature May (°C)	0.0908
Rainfall	
Rainfall of cropping season(mm)	0.2318
Rainfall October (mm)	-0.0358
Rainfall November (mm)	0.4351*
Rainfall December (mm)	-0.1397
Rainfall January (mm)	-0.2859
Rainfall February (mm)	0.3906*
Rainfall March (mm)	0.4299*
Rainfall April (mm)	0.2252
Rainfall May (mm)	-0.2418
Relative Humidity	
Relative Humidity of cropping season (%)	0.6469*
Relative Humidity October (%)	0.1993
Relative Humidity November (%)	0.2711
Relative Humidity December (%)	0.3482
Relative Humidity January (%)	0.0268
Relative Humidity February (%)	0.6764*
Relative Humidity March (%)	0.5117*
Relative Humidity April (%)	0.4294*
Relative Humidity May (%)	0.1512
*Significant at 0.05	

Table.8 Weather based yield forecast model equation

Model Equation	R^2	RMSE	Std. Error of Estimates
Yield = 276.18 + (91.45 × X_{22}) + (-12.48 × X_{31}) + (44.96 × X_{20}) + (1.07 × X_8)	0.69	61.14	68.03
Where, X_{22} = Minimum temperature of February, X_{31} = Relative humidity of March, X_{20} = Minimum temperature of December, X_8: Rainfall of April			

Fig.1 Predicted and trends of actual onion seed yield over the period 26 years



	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Predicted	180.6	151.1	245.7	75.3	206.1	285.1	302.4	263.3	175.8	187.2	399.0	119.3	281.6	183.7	219.4	264.2	109.3	367.2	280.0	343.3	119.4	85.0	169.4	150.0	126.4	35.4
Actual	124.0	60.0	215.0	174.0	127.0	330.0	430.0	237.0	150.0	206.0	500.0	95.0	200.0	150.0	275.0	230.0	105.0	400.0	260.0	288.0	110.0	120.0	96.7	213.5	95.0	134.0

During the period 1995 to 2004, the mean rainfall decreased by 57.02 mm and during 2005 to 2014 it decreased by 183.14 mm over the baseline. It showed a variation of 29.24 per cent during last thirty years. Reduction in decadal rainfall could be attributed to decrease in annual rainfall over the years. There was a prominent decrease in rains in all the months except June. Present findings are in conformity with a study in which a decrease in rainfall in Kullu (1500-2000 m amsl) was recorded during two decades (1995-2014) over the base line (1985-1994) (Chand, 2016), but contradicting another finding which reported an increased per annum rainfall (5.22 cm) during 1995-2004 as compared to 1963-72 in Kullu valley (Kumar *et al.*, 2009).

Monthly variations in relative humidity (RH) (%)

Data presented in Table 5 revealed that maximum increase in mean monthly RH i.e. 3.96% and 0.94% was observed in the month of October which during both the decades over the base line. However, maximum variations of 20.24 per cent in RH were observed during April month. In a study an increasing trends in average RH for the months of April to June was observed (Kumar *et al.*, 2009). Reduction in RH in most of the months may be attributed to the reduced rainfall over the years.

Decadal variations in relative humidity RH (%)

The perusal of data presented in the Table 6 revealed that decadal RH during the period 1985 to 1994, 1995 to 2004 and 2005 to 2014 was 62.75%, 62.78% and 58.95%, respectively. The decadal RH increased by 0.03% during decade-1 (1995 to 2004), while it was decreased by 3.79% during decade-2 (2005 to 2014) over the base line (1985 to 1994). The less RH may be due to reduction in precipitation and increasing trend of temperature. The maximum variations of 6.35 per cent in RH were observed during last thirty years.

Correlation and regression analysis of onion seed productivity with weather parameters

In the present study a significant (significant at 95 % level of significance) positive correlation was observed between onion seed productivity and relative humidity for February (r = 0.6764*), relative humidity for cropping season (r = 0.6469*), relative humidity for March (r =0.5117*), rainfall for November (r = 0.4351*), rainfall for March (r = 0.4299*), relative humidity for April (r = 0.4294*) and rainfall for February (r = 0.3906*). Whereas, a significant negative correlation of onion seed productivity was observed with maximum temperature for October (r = -0.4213*). Negative correlation signifies that the increase in any of these parameters may cause reduction in onion seed productivity whereas positive correlation indicated that increase in any of these parameters will enhance the productivity.

Onion seed productivity was regressed with maximum temperature, minimum temperature, rainfall and relative humidity which predicted the onion seed productivity based upon regression equation developed for the selected area (Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP)). The equation has been presented in the Table 8 and can be used as pre-harvest seed yield forecast model for onion crop. The regression equation is composed of minimum temperature of February, relative humidity of March, minimum temperature of December and rainfall of April which were positively correlated (Table 7). The regression equation was used to predict the onion seed yield for

26 years and which was compared with the actual yield. By developing yield forecast model equation crop yield was predicted with an accuracy of 69 %. The predicted and actual yield showed nearly similar trends which have been depicted in the figure 1. The onion seed productivity over the last 26 years showed a fluctuating pattern with an overall decreasing trend at the rate of 2.58 kg ha^{-1} per year. Whereas, overall decrease in onion seed productivity in 26 years observed was 67.08 kg ha^{-1}. The model equation was validated using root mean square error (RMSE) which was 61.14 kg ha^{-1}. Standard error of estimates for model equation was 68.03.

The fluctuations in the final seed yield of the onion were due to the variations in the climatic components. The increase in the monthly average temperature of the seed production months (October to May) and reduction in rainfall especially during vegetative and reproductive growth of the onion plant would have reduced the seed yield. High temperature stress significantly reduced both grain and biomass yields (Amita *et al.*, 2015). The present findings are in agreement with a report where reduction in seed yield of cabbage var. Golden Acre was recorded between the period of 1981- 2004 (Chand, 2016).

Thus from the present study it can be concluded that changing climatic conditions in mid hills of Himachal Pradesh negatively affected the seed production of onion and some agro techniques such as planting dates, planting geometries, mulches etc. need to be standardized.

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