A-5957
[1-5]

RESEARCH ARTICLE   Indian Journal of Agricultural Research, Volume Issue : ()

Assessment of Weather Parameters on Per Cent Disease Incidence and Forewarning Models of *Fusarium* Wilt in Pigeonpea as Influenced by Different Sowing Windows

D. Nagaraju[1], S.B. Kharbade[2], S.N. Hasabnis[3], J.D. Jadhav[4],
A.A. Shaikh[5], R. Balasubramanian[6]

10.18805/IJARe.A-5957

ABSTRACT

Background: *Fusarium* wilt caused by *Fusarium udum* (Butler) var. *cajani* is one of the most important soil-borne diseases of pigeonpea capable of causing 30-100% loss in grain yield. So it is essential to establish the relationship with weather parameters and prediction of per cent disease incidence.

Methods: An experiment was laid out in split plot design with three replications and sixteen treatment combinations considering different varieties and sowing windows. Correlation and multiple linear regression equations were elucidated between weather parameters and per cent disease incidence (PDI) of *Fusarium* wilt on different pigeonpea varieties under different sowing windows during 2017-18 and 2018-19.

Result: The correlation of weather parameters with PDI of *Fusarium* wilt indicated that significant and positively correlation with maximum and minimum temperature and negative correlation with evening relative humidity. Among all sowing windows 30th meteorological week (MW) sowing window with the variety ICPH 2740 PDI for two weeks prior was significantly positively correlated with maximum temperature (0.871** and 0.919**) and morning relative humidity (0.727* and 0.056). The prediction of PDI of *Fusarium* wilt with multiple linear regression equations were recorded the highest R^2 valueas 95.5% in case of treatment combination of 30th MW and the variety Vipula.

Key words: Correlation, Forewarning models, *Fusarium* wilt, PDI, Sowing windows.

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millspaugh] is one of the major pulse crops of the tropics and subtropics. Pigeonpea is grown in an area of 4.43 m ha with a production of 4.25 m tons the productivity of 960 kg ha^{-1} in India (Anonymous, 2019). Pigeonpea is grown throughout the country, except the hilly regions where the winter temperature is very low. In India, Maharashtra, Andhra Pradesh and Gujarat are the major pigeonpea growing states.

The production and productivity of this crop has remained stagnant over the past three decades due to its vulnerability to biotic and abiotic stresses. Major cause of low productivity is the losses due to diseases. Among the diseases, wilt and sterility mosaic are important. Recent surveys have indicated that major losses in the pigeonpea are due to wilt disease which is caused by *Fusarium udum* Butler var. *cajani.* Losses ranging between 0.2 to 100 % have been estimated from India (Butler, 1906, Gade, 2002 and Suresh, 2013).

Wilt caused by *F. udum* is a devastating disease of pigeonpea gaining importance day by day due to increasing drought conditions in the country. This disease can occur at any stage of plant development, from young seedling to the pod-filling stage (Choudhary, 2010). Though the disease goes unnoticed in early stages and symptoms are yellowing followed by drying of leaves and finally death of few branches or entire plant. The chemical control of this disease is not only expensive but also ineffective owing to the seed as well as soil-borne nature of the pathogen.

Keeping these facts in view, the correlation between weather parameters and PDI of *Fusarium* wilt per net plot

[1]Department of Agricultural Meteorology, College of Agriculture, Pune-411 005, Maharashtra, India.
[2]College of Agriculture, Nandurbar-425 412, Maharashtra, India.
[3]Division of Plant Pathology, College of Agriculture, Pune-411 005, Maharashtra, India.
[4]Department of Agricultural Meteorology, College of Agriculture, Pune-411 005, Maharashtra, India.
[5]Oilseeds Research Station, Jalgaon-412 005, Maharashtra, India.
[6]India Meteorological Department, Pune-411 005, Maharashtra, India.

Corresponding Author: D. Nagaraju, Department of Agricultural Meteorology, College of Agriculture, Pune-411 005, Maharashtra, India. Email: dharavathnaga@gmail.com

How to cite this article: Nagaraju, D., Kharbade, S.B., Hasabnis, S.N., Jadhav, J.D., Shaikh, A.A. and Balasubramanian, R. (2022). Assessment of Weather Parameters on Per Cent Disease Incidence and Forewarning Models of *Fusarium* Wilt in Pigeonpea as Influenced by Different Sowing Windows. Indian Journal of Agricultural Research. DOI: 10.18805/IJARe.A-5957.

Submitted: 27-12-2021 **Accepted:** 29-06-2022 **Online:** 18-07-2022

on different pigeonpea varieties at different sowing windows and development of forewarning models of *Fusarium* wilt per net plot was studied during 2017-18 and 2018-19.

MATERIALS AND METHODS

The experiment was laid out in split plot design with three replications at Department of Agricultural Meteorology farm, College of Agriculture, Pune during 2017-18 and 2018-19. The treatments comprised of four varieties *viz.,* Vipula, Rajeshwari, BDN 711 and ICPH 2740 as main plot and four sowing windows *viz*., 24th MW (11th to 17th June), 26th MW (25th June to 01st July), 28th MW (9th to 15th July) and 30th MW (23rd to 29th July) as sub plot treatments. The geographical location of the site (Pune) was 18°32′N, latitude; 73°51E, longitude and 559 m above mean sea level (MSL) situated in the sub-tropical region (Plain Zone). The soil is medium black having depth of about 1 m. The average annual rainfall of Pune is 675 mm. Out of total rainfall, about 75 per cent is received during south-west monsoon, while remaining is received from north-east monsoon. In the month of July and August, maximum temperature ranged from 26 to 30°C. The minimum temperature varied from 6 to 10°C during winter from November to middle of February. The humidity during monsoon *i.e.,* from June to September is quite high during morning (about 85 to 93%) and the evening humidity is generally ranged between 43 to 83 per cent. Urea and Di-ammonium phosphate were used as sources of Nitrogen (N) and Phosphorus (P), respectively and applied as per recommendation *i.e*., 25 kg N and 50 kg P. The seeds were treated with Thiram@ 4 g per kg of seed followed by *Rhizobium* and phosphate solubilizing bacteria @ 10 g per kg of seed.

The PDI was correlated with the weather parameters *viz.,* maximum temperature (T_{max}), minimum temperature (T_{min}), rainfall (mm), morning relative humidity (RH I), evening relative humidity (RH II), bright sunshine hours (BSS), wind speed (WS) and evapotranspiration (EP) using standard statistical procedure as suggested by Gomez and Gomez (1984). The multiple linear regression analysis was also worked out between PDI and weather parameters using prediction equation,

$$Y = a+b1X1+b2x2+b3X3+.......+ bnXn$$

Where,

Y= Per cent disease incidence, 'a' as constant and 'b' as regression coefficients of independent variable 'X'.

RESULTS AND DISCUSSION

The data regarding correlation between weather parameters and incidence of *Fusarium* wilt on different pigeonpea varieties at different sowing windows are given in Table 1 and 2 and forewarning models for prediction of disease are given in Table 3. The overall linear multiple regression analysis was worked out between PDI of W0 week with weather parameters of two week prior (W-2) for all different treatment combinations.

Correlation between weather parameters and PDI of *Fusarium* wilt in different pigeonpea varieties at different sowing windows and forewarning models for prediction of incidence of *Fusarium* wilt are given below:

Vipula

During first sowing window (24th MW), PDI for two week prior (W-2) was significantly positively correlated with minimum temperature (0.622* and 0.553) and evening relative humidity (0.589* and 0.651*) whereas, it was negatively correlated with maximum temperature (-0.237 and -0.609) and bright sunshine hours (-0.445 and -0.592) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The prediction equation for Vipula and 24th MW indicated that an increase of one unit of minimum temperature, morning relative humidity and evening relative humidity increased the *Fusarium* wilt by 1.967, 1.576 and 0.297 units, respectively. These weather parameters collectively increased the *Fusarium* wilt to an extent of 82.8% (R^2=0.828).

During second and third sowing window (26th, 28th MW), PDI for two week prior (W-2) was non- significant positively and negatively correlated with weather parameters during the period of study.

During fourth sowing window (30th MW), PDI for two week prior (W-2) was significantly positively correlated with maximum temperature (0.839** and 0.664), morning relative humidity (0.521 and 0.097) and bright sunshine hours (0.406 and 0.526), whereas, it was negatively correlated with evening relative humidity (-0.281 and -0.464) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The prediction equation for Vipula and 30th MW indicted that an increase of one unit of maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall and bright sunshine increased the *Fusarium* wilt by 1.742, 1.558, 0.810, 0.092, 0.014 and 1.856 units, respectively. These weather parameters collectively increased the *Fusarium* wilt to an extent of 95.5% (R^2=0.955).

Rajeshwari

During first, second and third sowing window (24th, 26th and 28th MW), PDI for two week prior (W-2) were non-significant positively and negatively correlated with weather parameters during the period of study.

During fourth sowing window (30th MW), PDI for two week prior (W-2) was significantly positively correlated with maximum temperature (0.751** and 0.762), morning relative humidity (0.517 and 0.028) and bright sunshine hours (0.354 and 0.623*), whereas, it was negative correlated with evening relative humidity (-0.208 and -0.576) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The prediction equation for Rajeshwari and 30th MW indicated that an increase of one unit of maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall and bright sunshine increased the *Fusarium* wilt by 2.090, 0.952, 0.543,

Table 1: Correlation between occurrence of *Fusarium* wilt disease of pigeonpea with weather parameters during *kharif* 2017-18.

Treatment		r' values							
Sowing window	Variety	T_{max}	T_{min}	RH-I	RH-II	Wind speed	Rainfall	Epan	BSS
24th MW	Vipula	-0.237	0.622*	-0.327	0.589*	0.217	0.466	-0.106	-0.445
26th MW	Vipula	0.238	0.428	0.093	0.239	-0.249	0.349	0.090	-0.047
28th MW	Vipula	0.592*	0.123	0.436	-0.086	-0.586	0.298	0.148	0.290
30th MW	Vipula	0.839**	0.053	0.521	-0.281	-0.713*	0.414	0.072	0.406
24th MW	Rajeshwari	-0.246	0.584*	-0.273	0.560	0.190	0.489	-0.124	-0.423
26th MW	Rajeshwari	0.182	0.429	0.096	0.300	-0.212	0.401	0.098	-0.105
28th MW	Rajeshwari	0.568	0.161	0.402	-0.074	-0.557	0.278	0.155	0.277
30th MW	Rajeshwari	0.751**	0.031	0.517	-0.208	-0.695*	0.502	-0.018	0.354
24th MW	BDN 711	-0.391	0.608*	-0.422	0.610*	0.352	0.434	-0.234	-0.516
26th MW	BDN 711	0.268	0.321	0.148	0.156	-0.292	0.227	0.082	0.013
28th MW	BDN 711	0.586*	0.154	0.412	-0.059	-0.578	0.334	0.099	0.267
30th MW	BDN 711	0.790**	-0.006	0.542	-0.276	-0.720*	0.487	-0.034	0.398
24th MW	ICPH 2740	0.255	0.455	0.029	0.253	-0.220	0.355	0.013	-0.074
26th MW	ICPH 2740	0.586*	0.097	0.487	-0.107	-0.640*	0.265	-0.035	0.300
28th MW	ICPH 2740	0.766**	-0.066	0.608*	-0.325	-0.773**	0.199	0.027	0.492
30th MW	ICPH 2740	0.871**	-0.313	0.727*	-0.618*	-0.813**	0.096	0.054	0.695*

Where, T_{max}: Maximum temperature; RH-I: Morning relative humidity; WS: Wind speed Epan: Pan evaporation; *Significant at 0.05% level.
T_{min}: Minimum temperature; RH-II: Evening relative humidity; RF: Rainfall; BSS: Bright sunshine hours; **Significant at 0.01% level.

Table 2: Correlation between occurrence of *Fusarium* wiltdisease of pigeonpea with weather parameters during *kharif* 2018-19.

Treatment		r' values							
Sowing window	Variety	T_{max}	T_{min}	RH-I	RH-II	Wind speed	Rainfall	Epan	BSS
24th MW	Vipula	-0.609*	0.553	0.184	0.651*	0.525	0.140	-0.453	-0.492
26th MW	Vipula	-0.015	0.311	0.117	0.131	-0.037	-0.211	0.135	0.074
28th MW	Vipula	0.424	0.112	0.162	-0.251	-0.423	-0.287	0.443	0.393
30th MW	Vipula	0.664*	0.055	0.091	-0.464	-0.587	-0.197	0.661*	0.526
24th MW	Rajeshwari	-0.417	0.501	0.240	0.498	0.329	0.067	-0.281	-0.318
26th MW	Rajeshwari	-0.125	0.339	0.163	0.225	0.060	-0.171	0.044	-0.009
28th MW	Rajeshwari	0.465	0.134	0.131	-0.279	-0.441	-0.269	0.469	0.383
30th MW	Rajeshwari	0.762**	-0.037	0.028	-0.576	-0.653*	-0.289	0.758**	0.623*
24th MW	BDN 711	-0.432	0.501	0.201	0.506	0.385	0.018	-0.277	-0.336
26th MW	BDN 711	-0.073	0.313	0.117	0.172	0.008	-0.216	0.099	0.047
28th MW	BDN 711	0.528	0.048	0.025	-0.368	-0.509	-0.333	0.550	0.487
30th MW	BDN 711	0.635*	0.105	0.105	-0.423	-0.545	-0.155	0.637*	0.469
24th MW	ICPH 2740	-0.028	0.380	0.056	0.149	-0.014	-0.146	0.103	0.028
26th MW	ICPH 2740	0.589*	-0.028	0.096	-0.441	-0.549	-0.451	0.594*	0.542
28th MW	ICPH 2740	0.682*	0.025	0.176	-0.485	-0.588	-0.208	0.628*	0.523
30th MW	ICPH 2740	0.919**	-0.397	0.056	-0.835**	-0.847**	-0.519	0.839**	0.843**

Where, T_{max}: Maximum temperature; RH-I: Morning relative humidity; WS: Wind speed; Epan: Pan evaporation; *Significant at 0.05% level.
T_{min}: Minimum temperature; RH-II: Evening relative humidity; RF: Rainfall; BSS: Bright sunshine hours; **Significant at 0.01% level.

0.164, 0.022 and 1.648 units, respectively. These weather parameters collectively increased the *Fusarium* wilt to an extent of 92.1% (R^2=0.921).

BDN 711

During first, second and third sowing window (24th, 26th and 28th MW), PDI for two week prior (W-2) were non-significantly positively and negatively correlated with weather parameters during the period of study.

During fourth sowing window (30th MW), PDI for two week prior (W-2) was positively correlated with maximum temperature (0.790** and 0.635*) and bright sunshine hours (0.398 and 0.469), whereas, it was negative correlated with evening relative humidity (-0.276 and -0.423) and wind speed (-0.720* and-0.545) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The prediction equation for BDN 711 and 30th MW indicated that an increase of one unit of maximum

Table 3: Forewarning models for two week prior (W-2) prediction of percent disease intensity of *Fusarium* wilt during 2017-18 and 2018-19.

Treatment		Forewarning model	R^2
Sowing window	Variety		Value
24th MW	Vipula	Y= - 157.333–1.576(T_{max}) + 1.967(T_{min}) + 1.576(RH I) + 0.297(RH II)- 0.091(Rainfall) -2.912(BSS)	0.828
26th MW	Vipula	Y= - 249.741– 0.100(T_{max}) + 2.413(T_{min}) + 1.690(RH I)+ 0.609(RH II)- 0.120(Rainfall)-.343(BSS)	0.907
28th MW	Vipula	Y= -253.336+2.190(T_{max})+ 1.435(T_{min}) – 1.096(RH I)+ 0.722(RH II)- 0.032(Rainfall) + 5.243(BSS)	0.898
30th MW	Vipula	Y= -165.092 + 1.742(T_{max}) + 1.558(T_{min}) +0.810(RH I)+0.092(RH II) +0.014 (Rainfall) +1.856(BSS)	0.955
24th MW	Rajeshwari	Y= -173.833 – 1.424(T_{max}) + 2.028(T_{min}) +1.658(RH I)+0.319(RH II)- 0.078(Rainfall) +3.257(BSS)	0.848
26th MW	Rajeshwari	Y= -216.248 + 0.321(T_{max}) + 1.650(T_{min}) + 1.326(RH I) +0.657(RH II)-0.099(Rainfall) +4.775(BSS)	0.889
28th MW	Rajeshwari	Y= -225.751+ 1.721(T_{max}) + 1.531(T_{min}) +1.105(RH I) +0.532(RH II)- 0.042(Rainfall) +4.074(BSS)	0.893
30th MW	Rajeshwari	Y= -143.291+ 2.090(T_{max}) + 0.952(T_{min}) + 0.543(RH I)+ 0.164(RH II) +0.022(Rainfall) +1.648(BSS)	0.921
24th MW	BDN 711	Y= -140.145 – 2.344(T_{max}) + 2.443(T_{min}) +1.744(RH I) +0.042(RH II)- 0.089(Rainfall) +2.184(BSS)	0.804
26th MW	BDN 711	Y= -184.148 - 0.251(T_{max}) + 1.894(T_{min}) +1.163(RH I) +0.558(RH II)- 0.097(Rainfall) +5.033(BSS)	0.820
28th MW	BDN 711	Y= -276.035 + 3.089(T_{max}) + 1.365(T_{min}) + 1.365(RH I) +0.777(RH II)+0.045(Rainfall) +4.998(BSS)	0.905
30th MW	BDN 711	Y= -180.390 + 2.332(T_{max}) + 1.172(T_{min}) +0.834(RH I) +0.174(RH II) +0.018(Rainfall) +1.548(BSS)	0.936
24th MW	ICPH 2740	Y= -160.149 - 0.088(T_{max}) + 1.763 (T_{min}) +1.092(RH I) +0.349(RH II)- 0.072(Rainfall) +3.318(BSS)	0.825
26th MW	ICPH 2740	Y= -215.726 + 1.454(T_{max}) + 1.476(T_{min}) +1.294(RH I) +0.366(RH II)- 0.069(Rainfall) +2.865(BSS)	0.867
28th MW	ICPH 2740	Y= -205.307 + 1.697(T_{max}) + 1.583(T_{min}) + 1.181(RH I)+0.214(RH II)- 0.022(Rainfall) +2.477(BSS)	0.931
30th MW	ICPH 2740	Y= -42.626 + 0.099(T_{max}) + 1.279 (T_{min}) +0.305 (RH I) -0.255 (RH II) +0.044(Rainfall) +1.219(BSS)	0.937

temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall and bright sunshine hours increased the *Fusarium* wilt by 2.332, 1.172, 0.834, 0.174, 0.018 and 1.548 units, respectively. These weather parameters collectively increased the *Fusarium* wilt to an extent of 93.6% (R^2=0.936).

ICPH 2740

During first sowing window (24th MW), PDI for two week prior (W-2) was non-significantly positively and negatively correlated with weather parameters during the period of study.

During second sowing window (26th MW), PDI for two week prior (W-2) was significantly positively correlated with maximum temperature (0.586* and 0.589*) and morning relative humidity (0.487 and 0.096), whereas, it was negative correlated with evening relative humidity (-0.107 and -0.441), during *kharif* seasons of 2017-18 and 2018-19, respectively. The prediction equation for ICPH 2740 and 26th MW indicated that an increase of one unit of maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and bright sunshine increased the *Fusarium* wilt by 1.454, 1.476, 1.294, 0.366 and 2.865 units, respectively. These weather parameters collectively increased the *Fusarium* wilt to an extent of 86.7% (R^2=0.867).

During third sowing window (28th MW), PDI for two week prior (W-2) was significantly positively correlated with maximum temperature (0.766** and 0.682*) and morning relative humidity (0.608* and 0.176), whereas, it was negative correlated with evening relative humidity (-0.325 and -0.485) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The prediction equation for ICPH 2740 and 28th MW indicated that an increase of one unit of maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and bright sunshine increased the *Fusarium* wilt by 1.697, 1.583, 1.181, 0.214 and 2.477 units, respectively. These weather parameters collectively increased the *Fusarium* wilt to an extent of 93.1% (R^2=0.931).

During fourth sowing window (30th MW), PDI for two week prior (W-2) was significantly positively correlated with maximum temperature (0.871** and 0.919**), morning relative humidity (0.727* and 0.056), evaporation (0.054 and 0.839**) and bright sunshine hours (0.695 and 0.843**), whereas, it was significantly negative correlated with evening relative humidity (-0.618* and -0.835**) and wind speed (-0.813** and -0.847**) during *kharif* seasons of 2017-18 and 2018-19, respectively.

The prediction equation for ICPH 2740 and 28th MW indicated that an increase of one unit of maximum temperature, minimum temperature, morning relative humidity, rainfall and bright sunshine increased the *Fusarium* wilt by 0.099, 1.279, 0.305, 0.044 and 1.219 units, respectively. These weather parameters collectively increased the *Fusarium* wilt to an extent of 95.5% (R^2=0.955). *F.* wilt was highly correlated with weather parameters and the above all prediction equations were corroborated with Puran *et al.* (2017).

Chhetry and Devi (2014) found that *F.* wilt progress is slow during the early phases of growth but accelerates during the flowering and podding stage. The rate of infection was the highest in flowering and podding stage. Chaudhary *et al.* 2000 also showed that flowering stage of the crop has no association with wilting but temperature and moisture and resistance level of the pigeonpea genotype together determine the course of wilt development.

The weather parameters *viz.,* minimum temperature and rainfall besides rainy day played a significant role in the development of *F.* wilt incidence on pigeonpea crop (Patel *et al*. 2011). In fact, development of perithecial stage of *F. udum* is favoured by cloudy weather, high humidity and a combination of low and high temperature. Further, *F.* wilt was favoured by soil water holding capacity and soil temperatures.

Similar results were reported by Chandra *et al.* (2017) concluded that mean and maximum incidence of *Fusarium* wilt disease found to be significant positively correlated with maximum and minimum temperatures (°C) while morning and evening and evening RH (%), rainfall (mm) and rainy day were negatively correlated with the corresponding incidence. These results were confirmed with Usha and Dubey, 2010 and they studied that early sowing minimizes wilt incidence. Maximum and minimum ambient temperature and soil temperature were positively and significantly correlated with wilt incidence.

CONCLUSION

The correlation of weather parameters with PDI of *Fusarium* wilt indicated that significant positively correlation with maximum and minimum temperature. The prediction of PDI of *F.* wilt with multiple linear regression equations were recorded with good R^2 values in all treatment combinations. It could be used for forewarning models of *F.* wilt under Pune variable climatic conditions.

Conflict of interest: None.

REFERENCES

Anonynous, (2019). Pulses revolution from food to nutritional security. Min Agri. and FW (DAC and FW), GOI.

Butler, E.J. (1906). The wilt disease of pigeonpea and pepper. Agric. J. India. 1: 25-36.

Chandra, P., Sharma, O.P., Vnnila, S, Singh, N. and Yadav, K.S. (2017). Climatic relationship of pigeonpea *F.* wilt in hot arid ecoregion of Banaskantha, Gujarat. Ann. of Pl. Protect. Science. 25: 416-419.

Chaudhary, R.G., Kumar, K. and Naimuddin. (2000). Association of date of sowing, flowering and wilt incidence in pigeonpea (*C. cajan*). Indian J. of Agri. Sci. 70: 452-454.

Choudhary, A.K. (2010). A wilt-resistant line 'IPA 204' of long-duration pigeonpea (*C. cajan*)*. Indian J. of Agri. Sci. 80: 907-9.

Chhetry, G.K.N and Devi, T.R. (2014). Wilt epidemiology of pigeonpea [*Cajanus cajan* (L.) Millsp.] in organic farming system. J. of Agri. and Veterinary Sci. 7: 01-06.

Gade, R.M. (2002). Integrated disease management of pigeonpea wilt. Ph.D. Thesis Marathwada Agril. Univ. Parbhani, Maharashtra, India. Pp. 89.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research, Second edn. A Wiley-Interscience Publication, John Wiley and Sons, New York. Pp. 680.

Patel, S.I., Patel, R.I., Desai, A.G. and Patel, D.S. (2011). Morphological, cultural and pathogenic variability among *F. udum* and root dip inoculation for screening pigeonpea germplasm. J. Mycol. Pl. Pathol. 41: 57-62.

Puran, Ch., Sharma, O.P., Vennila, S., Singh, N. and Yadav, S.K. (2017). Climatic relationship of pigeonpea in hot arid in hot eco region of Banaskantha, Gujarat. Annals of Plant Prot. Sci. 25: 416-419.

Suresh, P., Mamta S. and Gopika, G. (2013). An updated review of biology, pathogenicity, epidemiology and management of wilt disease of pigeonpea [*C. cajan* (L.) Millsp.]. J. of Food Legumes. 26: 1-14.

Usha, M. and Dubey, S.C. (2010). Effect of environmental variables on development of *Fusarium* wilt in chickpea cultivars. Indian J. of Agri. Sci. 80: 233-00.