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Effect of climatic variability and weather factors on development of tomato early blight in a hot semi-arid region of Southern India

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ABSTRACT

Effect of cultivars, planting periods, weather and climatic variability on early blight (EB) severity was studied over six *kharif* seasons (2011-16) at Rajendranagar, Telangana. Wider seasonal variations in onset (July-September) and peak severity (September-November) of EB was noted coinciding with 1-7 and 9-14 weeks after transplanting, respectively. Mean EB severity was highest in 2012 on both calendar (47.8%) and crop age (64%) basis. EB severity on cultivars *viz.,* US 3140 (20.8%) and Lakshmi (21.8%) was significantly lower over Heemsohna (24.2%) and DS 810 (25.8%). Plantings of June-July had higher severity (27.9%) over August-September (19.1%). Maximum and minimum temperature besides rainfall variability over long term normals for 2011-16 was 0.7 °C, 0.8 °C and 3.6 mm/week, respectively with their corresponding actuals of 31.8 °C, 22.5 °C and 28.3 mm/week. Negative impact of increasing minimum and maximum temperature and positive effect of increasing rainfall on EB severity was documented. Significant associations of EB severity with weather and climatic variability similar over seasons indicated evolving adaptations of early blight to climate change.

Key words: *Solanum lycopersicum*, *Alternaria solani*, planting period, climatic variability.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a major vegetable crop grown across the world with production contributed by China, India, USA, Turkey, Egypt, Iran, Italy and Spain. In India, tomato is cultivated in Madhya Pradesh, Karnataka, Andhra Pradesh, Telangana, Odisha, Gujarat and West Bengal over an area of 0.79 M ha with production of 19.75 MT (Anonymous, 2). One of the major reasons for lower productivity (24.2 tons/ha) of tomato in India against world (34 tons/ha) is due to yield loss caused by insect pests and diseases. *Alternaria solani* (Ellis and Martin) Sorauer, which cause early blight has worldwide distribution. Early blight is a serious menace across India since its first report from Delhi (Chona *et al.*, 6). Symptoms of *A. solani* on tomato is characterized by initial appearance of brown to dark leathery necrotic spots on leaflets followed by coalescing concentric lesions on leaf surface. Heavy defoliation occurs with disease progression resulting in yield loss. Infection occurs during warm and humid conditions. Early blight is becoming more severe on tomato partly due to warmer temperatures experienced worldwide (Keinath *et al.*, 9). In India, frequency of disease epidemics has increased due to climate change. While weather fluctuations consider the actuals of atmospheric conditions, climate variability incorporates deviations of actuals from long-term average (often referred as 'normals') with both of them implicit under climate change (Abrol and Gadgil, 1). The polycyclic early blight pathogen invades aerial parts of plants and is subjected continuously to weather fluctuations. In addition, genetic base of cultivars and cultivation practices determine the severity of disease. In the present study, dynamics of tomato early blight severity was studied with major objective of determining the effect of cultivars, planting dates in addition to weather cum climatic factors at Rajendranagar in Telangana.

MATERIALS AND METHODS

Investigation was a part of information and communication technology (ICT) based pest surveillance implemented to develop database for study on pest dynamics in relation to climate change on tomato at Rajendranagar (17:19:23N; 78:23:25E) located at Ranga Reddy district of Telangana. Tomato fields of farmers located near to the Vegetable Research Station of Sri Konda Laxman Telangana State Horticultural University, Rajendranagar (TS) were selected during each *kharif* (June-September) season between 2011 and 2016. Tomato hybrids *viz.*, Heemsohna, US 3140, DS 810, Lakshmi, US 440, US 618, US 869, Shubham, and Lyco hybrids were the cultivars planted by farmers and the number of fields under a particular cultivar varied across study seasons. Planting periods of tomato seedlings in main fields varied between June first and September second fortnights during each season. Planting of seedlings were done at a spacing

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of 90 × 60 cm. Tomato production practices such as fertiliser application (50:100:100 NPK/ha), drip or open furrow irrigation, staking of grown up plants four weeks of planting and need based pest management were adhered to by the farmers.

Disease surveillance was carried out in ten fields selected amongst tomato growers during each season with details of cultivars grown and planting dates noted. Each selected field had a minimum area of one-acre. Commencement of sampling coincided with appearance of symptoms of *A. solani* infection. Five spots per field were sampled with observations of disease grade on ten plants per spot. Observations were taken between disease appearance and crop maturity on weekly basis following the standard visual assessment of 0 - 5 scale for early blight was adopted based on per cent area of plant infected *viz.,*0: no symptoms; 1: 1-4%; 2: 5-10%; 3: 11-25%; 4: 26-50% and 5:>50%.

Per cent severity of early blight for each spot and of each field was calculated using the formulae given below.

Severity grade per spot (S_i)

$$S_i = 100 \times \sum_{j=0}^{J} \frac{j \times y_{ij}}{10 \times J}$$

Severity grade per field (Sp)

$$S_p = \frac{1}{I} \sum_{i=1}^{I} S_i$$

where, i= spot no, (1,2,…,5); j= severity grade (0,1,…,5); J= maximum disease grade; I=total number of spots; y_{ij} =number of plants in i^{th} spot with j^{th} severity grade. Mean severity across five spots per field for a given week of observation was calculated for individual fields. Data sets on progression of disease amongst sampled fields along standard meteorological weeks (SMW) were compiled for six seasons. Severity of early blight on basis of crop age (CA) (expressed in weeks) with respect to each period of observation was calculated considering their respective periods of planting in individual fields. Data sets were assembled on the disease dynamics pertaining to fields with common cultivars (Heemsohna, US 3140, DS 810 and Lakshmi) and periods of planting (PP) grouped into two (June & July (PP I) and August & September (PP II). Mean severity of early blight in respect of cultivars and PP was worked out for individual seasons.

Daily data of weather recorded at meteorological observatory of Vegetable Research Station, Rajendranagar (TS) were obtained pertaining to *kharif* season (June-November) on SMW basis for 2011-2016. The variables of weather collected were maximum and minimum temperature (MaxT & MinT in °C), morning and evening humidity (RHM & RHE in %), sunshine hour (SS in h/day), wind velocity (Wind in m/h) and total rainfall (RF in mm). For the variables of MaxT, MinT and total RF, climatic 'normals' (40 years average of respective variables) on SMW basis pertaining to periods of disease observations (29-47 SMW) were obtained from All India Coordinated Research Project on Agro Meteorology, Hyderabad. Climatic variability of MaxT, MinT and RF was worked out as deviations between actual values and 'normals' of each variable for all individual study seasons (2011-16) on SMW basis for further use in developing relations with early blight severity.

Data on severity of early blight in terms of SMW and crop age were analysed across seasons (2011-16) using one way analysis of variance (ANOVA) with null hypothesis that mean severity of the disease did not differ among different study seasons and the means were compared using Duncan's multiple range test (DMRT). Disease progression curves were constructed using second order polynomial degree for the four study cultivars (Heemsohna, US 3140, DS 810 and Lakshmi) and two planting periods (June & July (PP I) and August & September (PP II)) using the pooled data across seasons. One way ANOVA and 't' test assuming equal variances were applied on severity of early blight pooled over seasons in respect of cultivars and periods of planting. Data on MaxT, MinT and RF pertaining to disease observation periods (27- 49 SMW) across different seasons were subjected to one-way ANOVA to find out weather (using actual values) fluctuations as well as climatic (using deviations from 'normals') variability. Student 't' test with equal variances was used to quantify the magnitude of climatic variability for MaxT, MinT and RF considering actual and 'normal' data sets of 2011-16. Kendall's correlation coefficients were worked out between climatic variables of MaxT, MinT and RF (deviations of actual values from 'normals') and early blight severity for individual seasons as well as for data aggregated over all seasons. All statistical analyses were performed using SAS 9.4 software.

RESULTS AND DISCUSSION

In terms of calendar year (SMW based), early blight initiated as early as 29 SMW (July third week) in 2012 and the latest by 36 SMW (September first week) in 2011 and 2013 (Table 1). However, onset in terms of crop age indicated crop of one week after planting (WAP) during 2011 and seven WAP in 2015 and 2016 had shown initial symptoms thus indicating early or delayed onset of disease. Periods of peaks of severity in terms of SMW and crop age across seasons ranged from 36 to 46 SMW (September first to November second weeks) and 9 -14 WAP, respectively. Van der Waals *et al.* (17) found that early blight severity on tomato plants was directly proportional to inoculum concentration. Initial production of secondary spores by *A. solani* coincides with appearance of primary foliar lesions first on lower

Table 1. Disease severity of tomato early blight (*Alternaria solani*) across seasons.

Particulars	2011	2012	2013	2014	2015	2016
Period of onset* SMW (CA in weeks)	36 (1)	29 (4)	36 (3)	33 (5)	34 (7)	32 (7)
Period of peak severity* SMW (CA in weeks)	42 (9)	46 (14)	46 (12)	38 (13)	37(12)	36 (13)
Peak disease severity*	24.6	97.6	44.5	40.8	58.2	26.4
Seasonal mean severity (%) (on SMW basis)$	16.3^{c}	47.8^{a}	20.8^{c}	13.6^{c}	37.2^{b}	19.1^{c}
Seasonal mean severity (%) (on CA basis)$	19.5^{c}	64.1^{a}	20.9^{c}	16.0^{c}	43.5^{b}	19.7^{c}

*: based on initial incidence across 10 fields; $: means with similar alphabet in row are not significantly different based on DMRT following one-way ANOVA at p<0.05; values in parentheses correspond to crop age expressed in weeks after planting.

(older) leaves (Rotem, 14). Mean seasonal severity across years indicated similar trends on calendar (SMW) as well as crop age (CA) basis. Highest mean severity was observed in 2012 followed by 2015. Four seasons *viz*., 2011, 2013, 2014 and 2016 had on par severity lower over 2012 and 2015. Variations in cultivar response (Carolan *et al*, 3), planting periods (Shukla and Anjaneyulu, 16) coupled with other agronomic practices (Meynard *et al*, 10) along with atmospheric weather variables (Ganie *et al*, 8) could determine the epidemic development.

Progress of disease in respect of cultivars pooled over seasons along crop age are depicted in Fig.1 with respective trends described as polynomial equations (Table 2) of second order. Cultivar effects of early blight was noted in terms of onset and rate of progression on four commonly grown tomato hybrids. Early onset at least by a week in Heemsohna, Lakshmi and US3140 with similar rate of progression up to four WAP was noted. Disease severity increased with crop age. Rate of progression was similar for Heemsohna and US 3140 till crop maturity unlike Lakshmi which had higher rates beyond four WAP. On the other hand, DS 810 had slow progression till seven WAP with steep increase thereafter. Wilcoxson *et al.*, (18) attributed slow disease development and progress in some cultivars to varied

Table 2. Cultivar effects on early blight severity.

Cultivar	Equation on disease progression	Mean severity (%) pooled over seasons*
Heemsohna	$= -0.12x^2 + 4.27x$ ($R^2 = 0.56$)	24.2^{a}
US 3140	$= -0.09x^2 + 3.92x$ ($R^2 = 0.78$)	20.8^{b}
DS 810	$= 0.67x^2 - 1.24x$ ($R^2 = 0.98$)	25.2^{a}
Lakshmi	$= 0.19x^2 + 3.18x$ ($R^2 = 0.95$)	21.8^{b}

*: means with similar alphabet as superscript in a row are not significantly different based on DMRT following one-way ANOVA performed aggregate data over seasons for each cultivar.

vertical or horizontal resistance of cultivars. Report of Heemsohna being moderately resistant to early blight is available (Rani *et al.*, 13). DS 810 and Heemsohna had on par mean severity significantly higher over US 3140 and Lakshmi indicated lesser vulnerability of later cultivars (Table 2). Weekly fluctuations in symptomatic leaves declined due to disease induced leaf dehiscence and appearance of new asymptomatic leaves (Copes and Scherm, 7). Bimodal disease curves due to emergence of new healthy leaves (Pandey *et al*, 12) have been reported in addition to

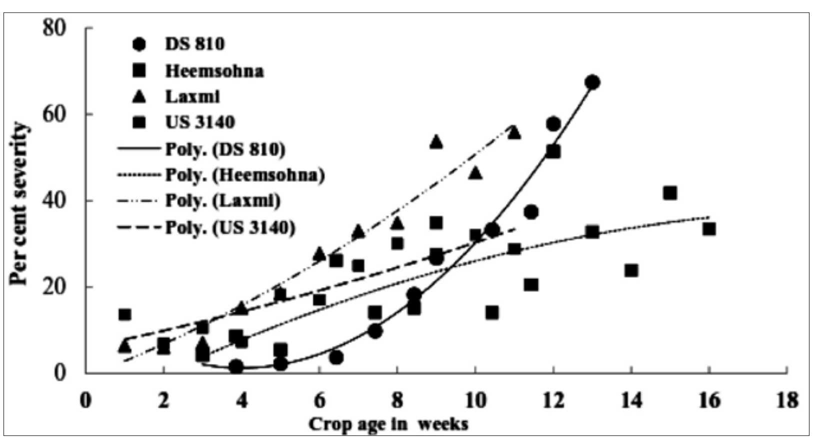

Fig. 1. Early blight disease progression in relation to cultivars.

increased susceptibility associated with older and senescing leaves (Nash and Gardner, 11).

Progression of early blight described along crop season using second order polynomial curves in respect of two planting periods PP I (June & July-early plantings) and PP II (August & September-late plantings) are shown in Fig.2. Initial rate of progression of early blight was higher for late over early plantings up to eight weeks of crop age possibly due to the availability of inoculum from the early plantings. However, steeper rate of progression observed with early over late plantings beyond mid-season indicated relative susceptibility of early plantings to early blight. Significantly higher mean disease severity in (27.9%) over late (19.1%) plantings described by equations also confirm the above finding by way of the opposite signs associated with intercept and coefficient (Table 3). The drop in disease progress in late plantings could also be due to many cultivars carrying different levels of resistance to early blight besides number of cultivars in the mixture influencing the disease progress. In the present study, the groupings for PP I accounted five cultivars, and that of PP II had eight cultivars and the later PP had significantly lower severity as well as slower rate of progression. Cultivar mixtures reducing disease progress through dilution, barrier, induced resistance and modification of microclimate were reported by Castro (4). Hence, the confounding effect of cultivars and planting periods are quite clear.

Table 3. Dates of sowing effects on early blight severity.

Date of sowing	Equation on disease progression	Mean severity (%) pooled over seasons*
June & July (PP I)	$= 0.42x^2 - 1.35x$ ($R^2 = 0.95$)	27.9[a]
August & September (PP II)	$= -0.13x^2 + 3.39x$ ($R^2 = 0.74$)	19.1[b]

*: means in a column with similar alphabet as superscript are not significantly different based on 't' test with equal variances (n_1=172 and n_2=198).

Approach of analysing inter seasonal variability for actual weather and of deviations offered scope for understanding the climate change and to further proceed with working out climate variability-disease severity relations. Range of A-MaxT, A-MinT and A-RF across crop seasons was 30.1-32.1°C, 22-23°C and 21- 44.8 mm/week, respectively. Climatic variables viz., D-MaxT, D-MinT and D-RF had values of -0.32 to 1.7°C, 0.4 to 1.5°C and -2.5 to 18.1 mm/week, respectively. While one-way ANOVA on weather (A) variability indicated significance for A-MaxT alone, D-MaxT and D-MinT showed significance across seasons. 2014 and 2015 had significantly higher A-MaxT over 2012, 2013 and 2016 with 2011 on par with all other seasons. Climatic variable D-MaxT had three groups with significantly higher values in 2014 and 2015 similar to A-MaxT. 2014 had the highest mean deviation for D-MinT that was on par with 2015 and 2012 followed by non-significant differences among 2011, 2012, 2015 and 2016. Means of weekly rainfall (both A-RF & D-RF) were not significant across seasons under weather as well as climatic situations (Table 4).

Early blight severity showed significant positive association with A-MaxT during 2011 and negative during 2013 and 2016. With A-MinT, the only significant association was negative in 2013. A-RF had shown negative and positive significance in respect of 2012 and 2016. Despite non-significant differences of A-MinT and A-RF across seasons as in Table 4, the significant association of these weather variables with disease severity in one or more seasons had arisen possibly due to their variations in distribution pattern. Such variations in respect of A-MinT in 2013 and A-RF during 2012 and 2016 possibly had an influence on disease

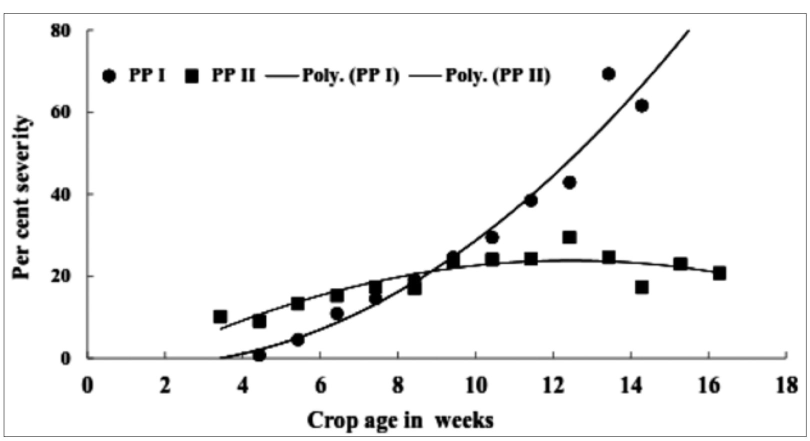

Fig. 2. Early blight disease progression in relation to planting periods.

Table 4. Weather fluctuations (A) and climatic variability (D) for study seasons.

Particulars	2011	2012	2013	2014	2015	2016	F	Significance of F#
Weather variability								
A-MaxT	31.2[ab]	30.7[b]	30.8[b]	32.0[a]	32.1[a]	30.1[b]	3.8	**
A-MinT	22.2	22.4	22.0	23.0	22.5	22.0	1.1	NS
A-RF	26.7	32.5	27.9	24.1	21.0	44.8	0.8	NS
Climatic variability								
D-MaxT	0.8 [b]	0.3[bc]	0.4[bc]	1.6[a]	1.7[a]	-0.3[c]	4.9	***
D-MinT	0.6[b]	0.8[ab]	0.4[b]	1.5[a]	1.0[ab]	0.4[b]	2.6	*
D-RF	0.04	5.8	1.2	-2.5	-5.6	18.1	0.8	NS

#: significance of 'F' denoted by *: p<0.05 ; **: p<0.01; NS: non significant.

dynamics of early blight. Effect of climate variability had similar significance as that of actual weather but for non-significance with D-MaxT. Significance of D-MinT association with disease was similar to that of A-MinT although weather and climatic variabilities for MinT was significant and non-significant, respectively across seasons (Table 5). On the other hand, the associations of A-RF and D-RF were negatively and positively significant during 2012 and 2016, respectively despite non-significant differences of RF across seasons for weather and climatic terms. Similarity of associations between weather and climatic variables indicated the ongoing adaptability of early blight organism to changing climate.

Magnitude of climatic variability over seasons (2011-16) quantified using normals of MaxT, MinT and RF indicated their significant increase to the tune of 0.7^{v}C, 0.8°C and 3.6 mm/week, respectively with their distributions also displaying significance as observed through significance of equality of variances (Table 6). Such a significance for mean and variances only emphasized the observed seasonal variability for associations in respect of individual seasons. Kendall correlations worked out between early blight severity, weather and climatic variability values considered over seasons (2011-16) indicated negative significance of A-MinT and of D-MaxT. D-RF had positive influence on early blight severity. Significant positive association of rainfall and relative humidity on the growth and development of early blight is well known (Chaerani and Voorrips, 5).

Early blight is the most damaging in regions of heavy rainfall, high humidity, and high temperatures (24°– 29°C) (Rotem and Reichert, 15). Mean temperature during the different seasons (2011-16) of the present investigation ranged between 26.4 and 27.5°C within limits of congenial conditions. June and July plantings were found better over August and September periods and cultivars US 3140 & Lakshmi were less vulnerable over DS 810 and Heemsohna to early blight at Telangana. Climatic variability during the recent periods (2011-16) over the past 40 years had an impact on early blight disease severity in the Telangana region of Southern India and future status incumbent upon changing temperature and rainfall *vis a vis* adaptability of the pathogen.

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Table 5. Association of actual weather (A) and climatic deviations (D) with early blight severity for individual seasons.

Variable	2011	2012	2013	2014	2015	2016
Early blight associations with weather variability (Kendall's 'τ' values) #						
A-MaxT	0.57**	0.20	-0.48*	-0.14	-0.33	-0.60*
A-MinT	0.007	-0.26	-0.56**	-0.35	-0.33	-0.20
A-RF	0.06	-0.34*	0.27	-0.40	0.33	0.69*
Early blight associations with climatic variability (Kendall's 'τ'values) #						
D-MaxT	0.085	0.100	-0.21**	-0.116	0.012	-0.51**
D-MinT	-0.025	-0.001	-0.18*	-0.206	0.011	-0.18
D-RF	0.066	-0.22*	-0.001	-0.005	-0.104	0.62**

#: significance of 'τ' denoted by *: p<0.05; **: p<0.01.

Table 6. Association of actual weather and climatic deviations with early blight severity over seasons (2011-16).

Variables	Actual Mean (11-16)	Mean deviation from normal#	Kendall 'τ' values of early blight severity with	
			Actual (A) weather	Deviations (D) from normal
Max.T	31.8	0.7*	-0.04	-0.08*
Min.T	22.5	0.8**	-0.18*	-0.03
Rainfall	28.3	3.6***	0.03	0.10**

#: mean deviations (actual minus normal) of variables compared based on Student's t test; significance of 't' and 'τ' denoted by * $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

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REFERENCES

1. Abrol, Y.P. and Gadgil, S. 1999. Rice in a variable climate. (eds). APC Publishing House, New Delhi, pp. 252.
2. Anonymous. 2018. Horticulture statistics at a glance 2018. Government of India. Ministry of Agriculture and Farmers Welfare. Department of Agriculture, Farmers welfare. Horticulture statistics division. pp.481.
3. Carolan, K., Helps, J., Van D. B. F., Bain, R., Paveley, N. and Van D. B. F. 2017. Extending the durability of cultivar resistance by limiting epidemic growth rates. *Proc. Royal Society B: Biological Sciences*, **284:**1863. doi: 10.1098/rspb.2017.0828.
4. Castro, A. 2001. Cultivar mixtures. *The plant health instructor*. doi: 10.1094/PHI-A-2001-1230-01.
5. Chaerani, R. and Voorrips, R.E. 2006. Tomato early blight (*Alternaria solani*): the pathogen, genetics, and breeding for resistance. *J. Gen. Plant Pathol.* **72**: 335-47.
6. Chona, B.L., Lall G. and Kakaria, N.C. 1958. *The fungi of Delhi.* ICAR Publ., New Delhi, pp. 42.
7. Copes, W.E and Scherm, H. 2010. Web Blight Development on Container-Grown Azalea in Relation to Time and Environmental Factors. *Plant Dis.* **94**: 891-97.
8. Ganie, M.Y., Lone, A. H., Razvi, S. M., Mir, M. R. and Khalid, R. H. 2015. Role of weather factors on early blight of potato under kashmir valley conditions. *Molecular Plant Breeding*, **6:** 1-5 doi: 10.5376/mpb.2015.06.0004.
9. Keinath, A.P., Du, B.V.B., and Rathwell, P.J. 1996. Efficiency and economics of three fungicidal application schedules for early blight control and yield of fresh market tomato. *Plant Dis.* **80:** 1277-82.
10. Meynard, J.M., Dore, T., and Lucas, P. 2003. Agronomic approach: cropping systems and plant diseases. *Comptes Rendus Biologies*, **326:** 37-46.
11. Nash, A.F. and Gardner, R.G. 1988. Tomato early blight resistance in a breeding line derived from *Lycopersicon esculentum*. *Plant Dis.* **72:** 206-09.
12. Pandey, K.K., Pandey, P.K., Kallo, G. and Banerjee, M.K. 2003. Resistance to early blight of tomato with respect to various parameters of disease epidemics. *J. Gen. Plant Pathol*. **69***:* 364-71.
13. Rani, S., Singh, R., Gupta, S., Dubey, S. and Razdan, V. K. 2015. Status, identification of resistant sources and epidemiology of early blight of tomato in Jammu division of Jammu and Kashmir. *Indian Phytopath.* **68:** 1-2.
14. Rotem, J. 1994. The genus *Alternaria*: biology, epidemiology, and pathogenicity. American Phytopathological Society Press, St Paul, pp. 326.
15. Rotem, J. and Reichert, I. 1964. Dew - a principal moisture factor enabling early blight epidemics in a semiarid region of Israel. *Plant Dis. Reptr.* **48:** 211-15.
16. Shukla, V.D. and Anjaneyulu. A. 1981. Adjustment of planting date to reduce rice tungro disease. *Plant Dis.***65:** 409-411.
17. Van der Waals, J.E., Korsten, L., Aveling T.A.S. and Denner F.D.N. 2003. Influence of environmental factors on field concentrations of *Alternaria solani* conidia above a South African potato crop. *Phytoparasitica*, **31**: 353-364.
18. Wilcoxson, R.D., Shovm, B. and Asit, A.A. 1975. Evaluation of wheat cultivar for the ability to retard development of stem rust. *Ann. Appl. Biol.* **86:** 275-287.

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