Research Article

Relooking Yield Losses Caused by Maydis Leaf Blight, and Banded Leaf and Sheath Blight in Maize

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Abstract

Investigation on yield loss assessment in maize due to maydis leaf blight (MLB) and banded leaf and sheath blight (BLSB) were conducted during *Kharif* 2010-2014 under multi-locational fields of Northern India conditions. Result of field experiments revealed 12.69 per cent yield loss for MLB at Delhi while the yield loss was 42.66 per cent at Dhaulakuan during the years of 2010-2012. The yield loss for MLB was 19.71 per cent at Ludhiana during 2013-14. BLSB disease caused 13.66 per cent loss at Delhi during 2012-2013 whereas 20.62 per cent yield loss was recorded at Pantnagar during 2011-2013. Significant loss in grain yield (q ha^{-1}) was observed due to BLSB in unprotected plots as compared to protected treatments at across different locations. Present study revealed a positive correlation for both diseases with weather parameters like Tmax, Tmin, relative humidity and rainfall. These results suggested that locations strongly influence disease incidence and grain yield probably due to environmental factors. The analysis of weather parameters with the incidence of MLB and BLSB disease of maize could be used by plant pathologists to develop or redesign management strategies for the maize growers.

Key words: Banded leaf and sheath blight, maize, maydis leaf blight, protected, unprotected, yield loss

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Maize, an important crop for food and nutritional security in India, is grown in diverse ecologies and seasons on an area of 8.71 m ha with production of 22.26 mt (GoI 2015). India ranks 4th in maize area in the world (Yadav et al 2014). To meet the rising demand, a quantum jump in maize production is the need of the hour (Srinivasan et al 2004). However, the production potential of the crop has not been fully exploited due to several biotic and abiotic factors. The crop suffers from many fungal diseases, of which foliar diseases take a heavy toll (Wang et al 2014). Among the diseases, maydis leaf blight (MLB) and banded leaf and sheath blight (BLSB) have become as a serious yield limiting factor in most maize producing regions of the country, especially in the Northern, Eastern and North-eastern India. Their geographical distribution in the agro-climatic zones is influenced by temperatures (high/low), humidity, cultural practices and; the type and diversity of maize cultivars used. Under favorable environmental conditions, these diseases play havoc and cause immense losses (Ali and Yan 2012).

Maydis leaf blight caused by the fungus [*Bipolaris maydis* (Drechs.) Drechs.] is a serious foliar disease of maize distributed widely in maize-producing areas across the world. It is reported from most maize growing regions but most devastating in hot and humid tropical and temperate areas of the world. It has the potential to cause grain yield losses of more than 70 per cent (Wang et al 2001). The currently predominant form of *C. heterostrophus* is Race O, which can cause yield losses of up to 65 per cent (Sharma and Rai 2005; Ali et al 2011; Mehra et al 2012). Damage is most critical if infection occurs prior to silking and if weather conditions are favourable for disease development during the reproductive growth stages. Occurrence of BLSB on maize, a soil-borne disease caused by *Rhizoctonia solani* f.sp. *sasakii* has been reported from several maize growing countries and is more prevalent in humid weather with temperature of around 28 C (Singh and Shahi 2012). The extent of losses is determined by degree of disease severity, susceptibility level of host and environmental conditions. With the introduction of high yielding genotypes, extensive use of fertilizers and continuous cropping system, there has been a phenomenal increase in the incidence of MLB and BLSB in India. Though, the magnitude of grain loss may go up to 100 per cent when ear rot phase of BLSB under incessant rainfall predominates, yet a yield reduction ranging between 10-40 per cent was estimated in different cultivars under artificially created disease epiphytotics (Singh and Sharma 1976; Mehra et al 2012). Management of MLB & BLSB is primarily focused on the use of resistant cultivars and foliar application of fungicides (Lackermann et al 2011). Efficacious use of foliar fungicides requires information about disease incidence and severity, in combination with knowledge of both the disease resistance characteristics of the cultivar and the different pathogen life cycles, and an understanding of the economic costs and benefits of fungicide application. Although a great deal of research has been done on maize diseases, currently there is minimal information available about the impact of diseases of maize in the country. It has been demonstrated that, when growers lack information on actual yield losses caused by the major diseases in maize, they are unable to make firm economic and agronomic decisions regarding disease management (Lackermann et al 2011). Although information on yield losses caused by MLB and BLSB diseases are available, but extremely limited studies have been conducted on the influence of environmental factors like temperature, rainfall and relative humidity. Therefore, analysis of weather parameters provides a base to take preemptive decision against the diseases under a given set of environmental conditions for better management practices. Keeping these points in view, the present study was undertaken to re-quantify crop yield losses caused by MLB and BLSB in maize which will facilitate decision making in proper management strategies at the disease onset itself.

Materials and Methods

Field experiments were conducted during 2010-2014 in the *Kharif* season at five locations namely, Hill Agricultural Research and Extension Centre (HAREC) – Dhaulakuan, HP, Govind Ballabh Pant University of Agriculture and Technology (GBPUAT), Pantnagar, Uttarakhand, Punjab Agricultural University (PAU) Ludhiana, Punjab and ICAR-Indian Agricultural Research Institute (IARI), New Delhi. The experiment on yield loss estimation due to MLB was conducted at HAREC, PAU and IARI, while the losses due to BLSB disease, the experiments were performed at GBPUAT and IARI. The yield losses due to MLB and BLSB were assessed separately. For estimation of yield losses, susceptible variety Vivek QPM 9 was used for BLSB and Malvia Hybrid 2 for MLB. The plot size was 3 × 3 min paired blocks with protected and unprotected treatments. In protected plots of MLB, the experiment on Mancozeb @ 0.25% was sprayed two times at 30 DAS (days after sowing) and 45 DAS. Prior to fungicide spray, the crop was inoculated once with sorghum based mass culture of *B. maydis* at 25 DAS following the method of Payak and Sharma (1983). In case of BLSB, the crop was inoculated with barley based mass culture of *R. solani* f.sp. *sasakii* at 35 DAS (Ahuja and Payak 1978) and Validamycin @ 2.7 ml/litre was sprayed two times at 3 DAI (days after inoculation) and 15 DAI in protected plot. In non-protected plots of both diseases, plain water was sprayed on the inoculated plants. Each treatment was replicated nine times. The severity of the MLB and BLSB was recorded at 1-5 incidence scale

(Ahuja and Payak 1983). The per cent disease index was calculated by using the formula given by Wheeler (1969). The avoidable yield loss in both the diseases was calculated using observed values in protected and corresponding unprotected treatment values using the formula:

Per cent avoidable loss = (Vp – Vu) / Vp × 100

where, Vp = values of protected plot and

Vu = values of unprotected plot.

The data collected from all the locations were statistically analyzed using an analysis of variance (ANOVA) to determine the least significant difference ($P < 0.05$).

Weather data on various weather parameters were collected from all the centres. These data and disease development of MLB and BLSB diseases were subjected to statistical analysis (Khan et al 2017) to observe the positive or negative correlations, if any existed.

Results and Discussion

Yield and yield affecting factors were compared for chemically protected and non protected maize plants. The pooled data of MLB obtained in 2010-12 at Delhi (Table 1), revealed that, the grain yields of maize differed significantly in protected (61.47 q ha^{-1}) and unprotected treatments (53.67 q ha^{-1}) with per cent disease incidence of 21.7 and 24.7. The yield loss of MLB in 2010 under protected plots, was 69.79 q ha^{-1} with the mean of 18.0 per cent disease incidence. Yield of un-protected plot was 62.40 q ha^{-1} and total 10.45 per cent yield was lost due to MLB disease. The experiment was further repeated in *Kharif* 2011 and the disease development during the crop season was more as compared to 2010 with mean disease incidence of 24.1 occurred in non protected plots, which yielded 62.78 q ha^{-1} whereas average yield in protected plot was 73.03 q ha^{-1}. Yield loss due to MLB during 2011 was 14.04 per cent. The data indicated that loss in grain yield was directly proportional to the intensity of infection in cropping season. In 2012, under protected conditions, there was a significant increase in grain yield (41.02 q ha^{-1}) with a disease incidence of 24.1, whereas, grain yield in non-protected plot was 35.82 q ha^{-1} with disease incidence of 28.0 and total 12.67 per cent losses was recorded for MLB disease. The correlation study between percent disease incidence and weather parameters revealed that the disease incidence is positively correlated (Figs 1-5) in protected or unprotected treatments with Tmax (0.4944 & 0.9427), Tmin (0.9955 & 0.7848), RHmax (0.7109 & 0.997), RHmin (0.8352 & 0.9829), and negatively correlated rainfall (0.4641 & 9278). Jensen and Boyle (1965) through their studies on climatic elements had also reported the influence of temperature & relative humidity on the development of Cercospora leaf spot in groundnut. Similar findings were also recorded by Lokhande and Newaskar (2000) in India who observed that temperature range of 25-30 per cent and RH of 74-87 per cent were highly conducive for leaf spot development.

Assessment of avoidable yield loss due to MLB at Dhaulakuan (Table 2) during *Kharif*, 2010 revealed that the average yield in protected plot was 25.03 q ha^{-1} with disease incidence of 26.85 per cent whereas in non-protected plot yield was 20.82 q ha^{-1} with a disease score of 66.42 per cent and avoidable yield loss due to MLB was 49.86 per cent. Similarly in 2011, 58.67 per cent disease incidence of MLB occurred in non-protected plots, with a yield of 23.88 q ha^{-1} whereas average yield in protected plot was 37.30 q ha^{-1} with 36.40 per cent MLB disease incidence. Yield loss due to MLB during 2011 was 35.98 per cent. In 2012, the MLB incidence and crop yield loss were higher than previous two years in both protected and non protected plots and yield loss was 42.13 per cent. In 2010-12, Dhaulakuan had low yield compared with the Delhi location which was might be due to unusually high and higher duration of rainfall occurring in Dhaulakuan. The present study therefore indicated that, the yield loss not only depends on the level of disease severity alone but also on the geographical distances in the agro-climatic zones which are influenced by varying temperatures (high/low), humidity, cultural practices, type and diversity of maize cultivars used. Under favorable environmental conditions, these diseases play havoc and cause immense losses both in quantity and quality as well (Ali and Yan 2012). Correlation of disease development with

Table 1. Assessment of avoidable yield loss due to maydis leaf blight (MLB) at Delhi during *Kharif*, 2010-12

Treatment	Per cent disease incidence				Yield (q ha^{-1})				Yield loss (%)			
	2010	2011	2012	Pooled	2010	2011	2012	Pooled	2010	2011	2012	Pooled
Protected	18.0	22.0	24.1	21.7	69.79	73.03	41.02	61.47	–	–	–	–
Non-protected	22.1	24.1	28.0	24.7	62.40	62.78	35.82	53.67	10.45	14.04	12.67	12.69
CD (*p* 0.05)	0.18	N/A	0.12	0.05	4.16	9.31	2.59	3.64				
CV	8.18	9.41	4.25	2.31	5.71	12.42	6.10	5.73				

Table 2. Assessment of avoidable yield loss due to maydis leaf blight (MLB) at Dhaulakuan during *Kharif*, 2010-12

Treatment	Per cent disease incidence				Yield (q ha^{-1})				Yield loss (%)			
	2010	2011	2012	Pooled	2010	2011	2012	Pooled	2010	2011	2012	Pooled
Protected	26.85	36.40	37.73	33.66	25.03	37.30	39.57	33.97	–	–	–	–
Non-protected	66.42	58.67	67.37	64.16	20.82	23.88	24.81	23.17	49.86	35.98	42.13	42.66
CD (*p* 0.05)	3.59	9.06	2.91	2.91	N/A	2.23	4.14	5.13				
CV	6.97	17.27	5.03	5.40	72.93	6.61	11.66	16.28				

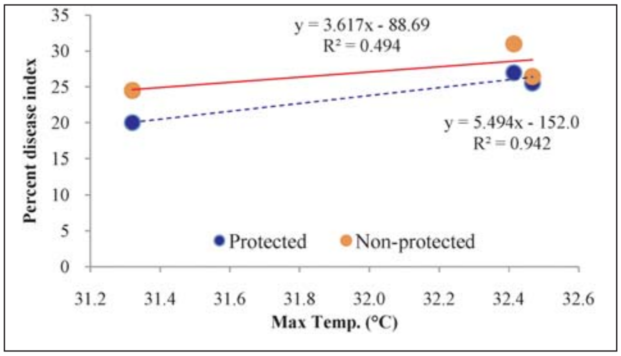

Figure 1. Effect of maximum temperature on the development of MLB at Delhi

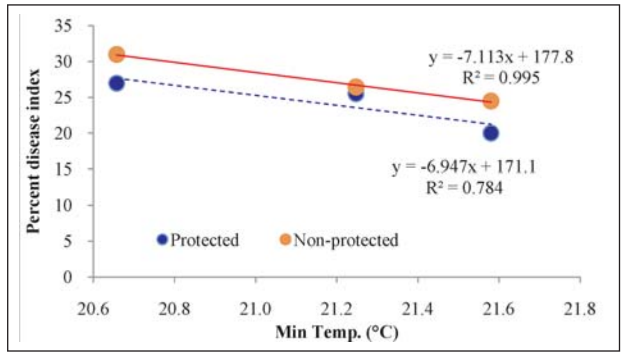

Figure 2. Effect of minimum temperature on the development of MLB at Delhi

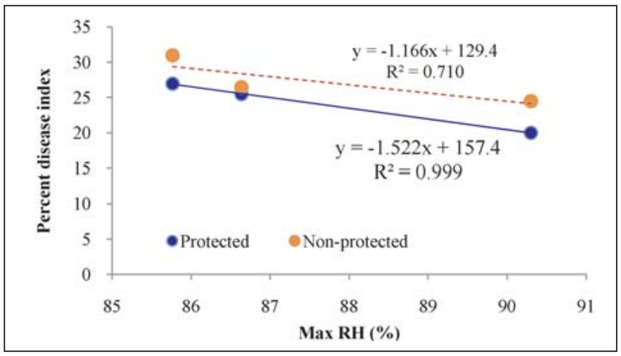

Figure 3. Effect of maximum RH on the development of MLB at Delhi

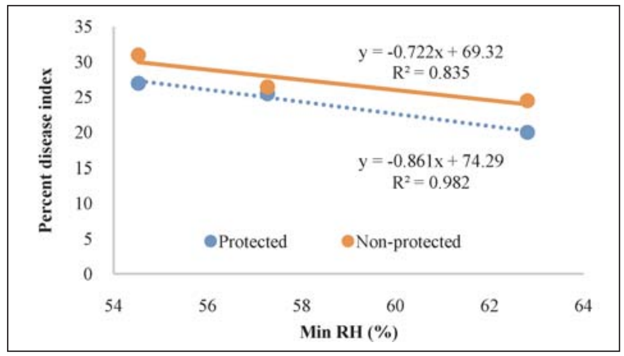

Figure 4. Effect of minimum RH on the development of MLB at Delhi

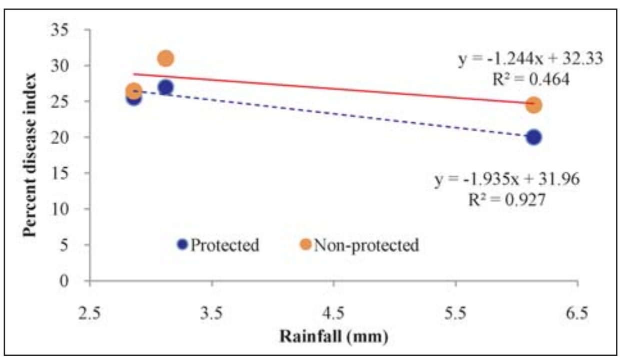

Figure 5. Effect of rainfall in the development of MLB at Delhi

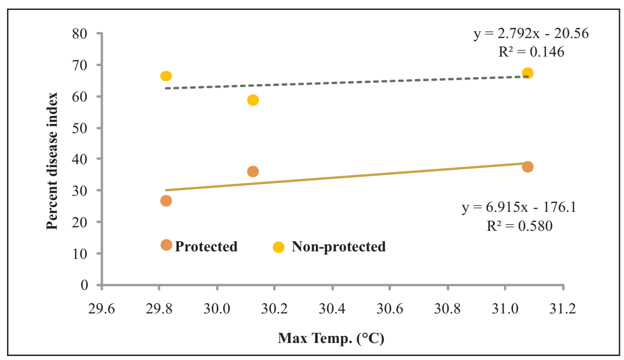

Figure 6. Effect of maximum temperature in the development of MLB at Dhaulakuan

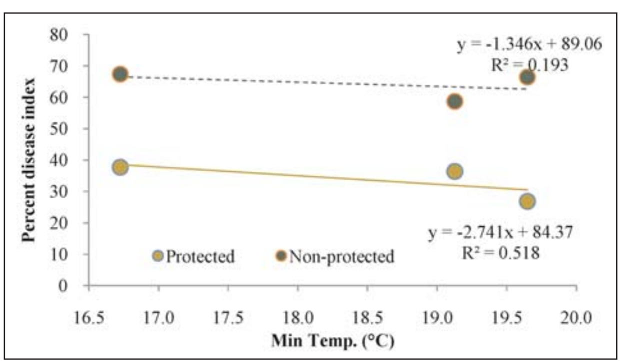

Figure 7. Effect of minimum temperature in the development of MLB at Dhaulakuan

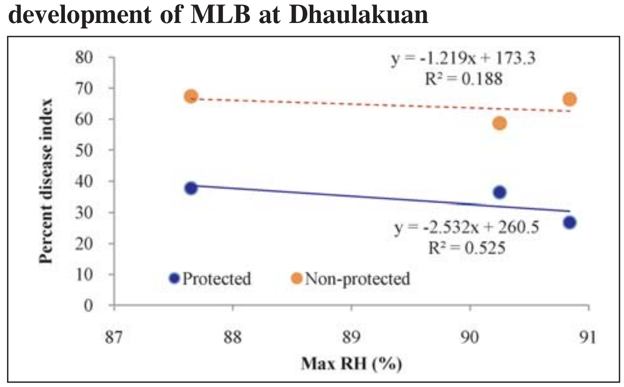

Figure 8. Effect of maximum RH in the development of MLB at Dhaulakuan

meteorological factors at Dhaulakuan revealed that the per cent disease intensity was positively correlated with the average maximum temperature (r = 0.58), and followed by average rainfall (r = 0.962) in cropping period (Figs 6-10).

Grain yield loss at Ludhiana due to MLB during *Kharif* 2014 was 57.24 q ha^{-1} in protected plots with 22.1 per cent disease incidence (Table 3). Grain yield was 45.62 q ha^{-1} in non-protected plots where MLB severity was 31.2 in 2014. The avoidable yield loss due to MLB severity was recorded 18.58 and 20.30 per cent during year 2013. When the data for 2013-2014 were pooled yield in unprotected plots (45.84 q ha^{-1}) was significantly less then protected maize plot (56.36 q ha^{-1}). It is evident higher the disease incidence more is the yield loss. The results of the present investigations could be corroborated with the findings of earlier workers (Wang et al 2001; Ali et al 2011; Raziq and Ahmed 1992; Rahman et al 2005). Chenulu and Hora (1962) studied losses due

Table 3. Assessment of avoidable yield loss due to maydis leaf blight (MLB) at Ludhiana during *Kharif*, 2013-14

Treatment	Per cent disease incidence			Yield (q ha^{-1})			Yield loss (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Protected	23.6	22.1	23.2	56.58	57.24	56.36	–	–	–
Non-protected	32.8	31.2	32.3	46.07	45.62	45.84	18.586	20.300	19.710
CD (p = 0.05)	0.24	0.18	0.20	1.18	1.56	3.24			
CV	7.98	6.42	6.66	2.09	2.75	5.75			

Table 4. Assessment of avoidable yield loss due to banded leaf and sheath blight (BLSB) disease at Delhi during *Kharif*, 2012-13

Treatment	Per cent disease incidence			Yield (q ha^{-1})			Yield loss (%)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Protected	22.8	21.6	22.2	45.97	71.04	58.51	–	–	–
Non-protected	37.5	29.1	33.3	39.38	61.65	50.51	14.33	13.21	13.66
CD (p = 0.05)	0.14	0.29	0.17	3.47	4.98	2.57			
CV	4.32	10.59	5.55	7.38	6.80	4.28			

Table 5. Assessment of avoidable yield loss due to banded leaf and sheath blight (BLSB) disease at Pantnagar during *Kharif*, 2012-13

Treatment	Per cent disease incidence			Yield (q ha^{-1})			Yield loss (%)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
Protected	27.7	23.3	23.8	35.98	36.94	47.48	–	–	–
Non-protected	46.6	45.0	39.5	25.52	24.20	37.69	29.07	34.48	20.62
CD (p = 0.05)	0.42	0.27	0.15	1.35	2.47	1.38			
CV	10.38	7.31	4.45	3.99	7.32	2.93			

P: Protected NP: non-protected

to leaf blight of maize in Bihar and reported that loss in grain yield varied from 27.60 to 90.70 per cent depending upon the intensity of infection and loss was directly proportional to the intensity of the disease. The correlation studies (Figs 11-15) at Ludhiana between percent disease incidence and weather parameters revealed that the disease incidence is positively correlated with all the weather parameters like Tmax, Tmin, RHmax, RHmin and rainfall (r =1). These results were in accordance with Datta and Senapati (2017) who found such positive correlation of weather factors with development of leaf spot diseases. Similarly, Harlapur et al (2000) reported that high rainfall coupled with low temperature during September increased the incidence of TLB and caused significant yield loss. Pandurangegowda et al (1994) also observed that the incidence of TLB of maize increased from June to October. Meteorological factors like temperature (22-38 C), relative humidity (72-98%) and rainfall (134-165 mm) have shown highly significant correlation with disease intensity. While, the rainfall showed a highly significant positive correlation with PDI.

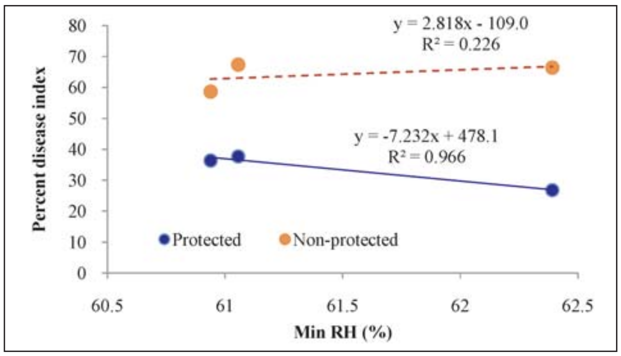

Figure 9. Effect of minimum RH in the development of MLB at Dhaulakuan

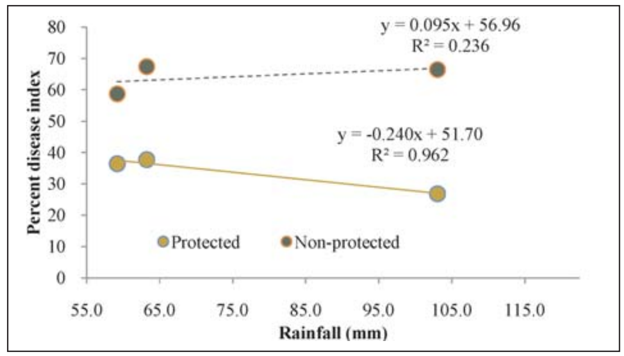

Figure 10. Effect of rainfall in the development of MLB at Dhaulakuan

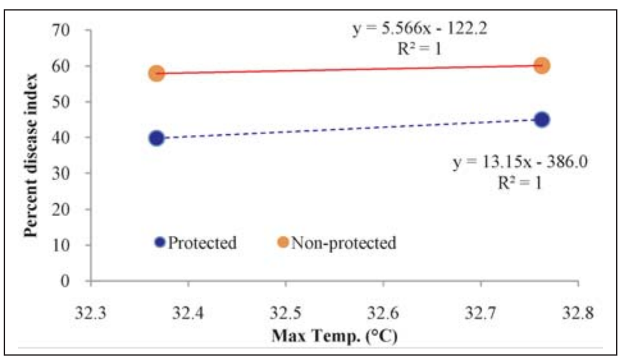

Figure 11. Effect of maximum temperature in the development of MLB at Ludhiana

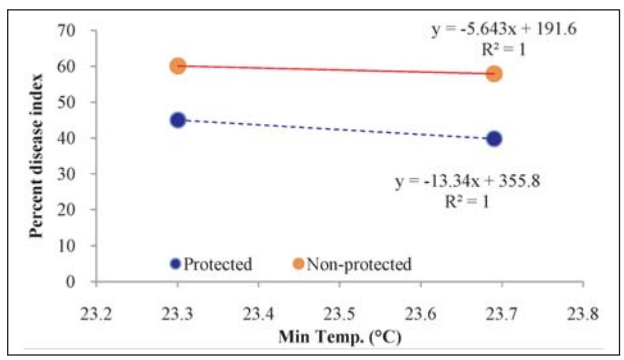

Figure 12. Effect of minimum temperature in the development of MLB at Ludhiana

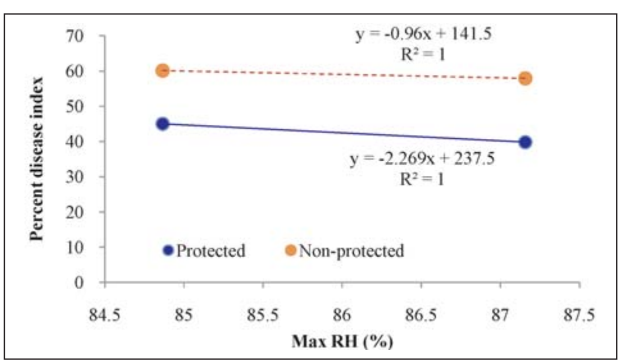

Figure 13. Effect of maximum RH in the development of MLB at Ludhiana

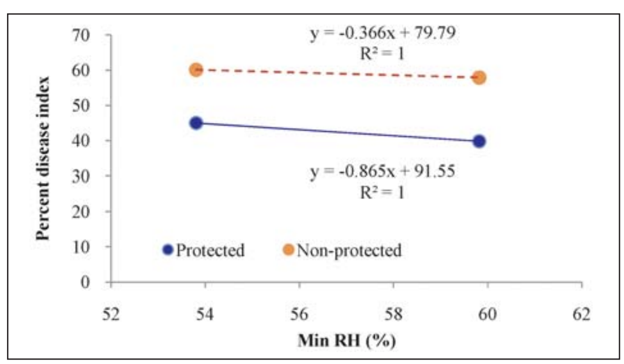

Figure 14. Effect of minimum RH in the development of MLB at Ludhiana

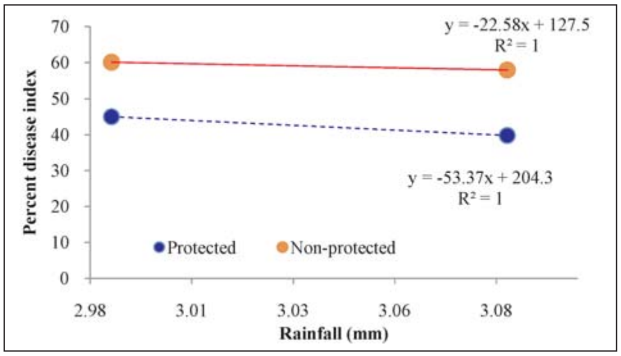

Figure 15. Effect of rainfall in the development of MLB at Ludhiana

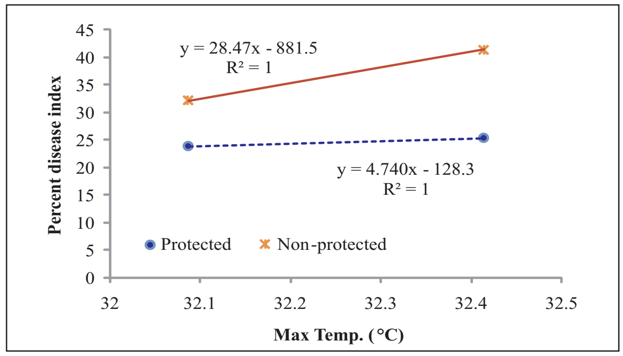

Figure 16. Effect of maximum temperature in the development of BLSB at Delhi

Pandurangegowda et al (1989) studied the incidence of *Exerohilum turcicum* on the susceptible *cv.* CM-202 sown at fortnightly intervals and reported that meteorological factors like temperature 22 to 38 C, relative humidity 72 to 98 per cent and rainfall 134 to 165 mm were correlated with increased disease intensity.

Maize yield loss caused by another important disease BLSB was also estimated. Trials conducted at Delhi in 2012 indicated that under protected conditions average yield was 45.97 q ha^{-1} with a disease incidence of 22.8 while in non protected plot average yield was 39.38 q ha^{-1} with 37.5 disease incidence and total avoidable yield loss was 14.33 per cent (Table 4). In 2013, under protected plots, there was a significant increase in grain yield (71.04 q ha^{-1}) with a disease incidence of 21.6 per cent, whereas, grain yield in non-protected plot was 61.65 q ha^{-1} with disease incidence of 29.1 and total 13.21 per cent losses were recorded in the variety Vivek QPM 9. The correlation studies for BLSB at Delhi revealed that the disease incidence is

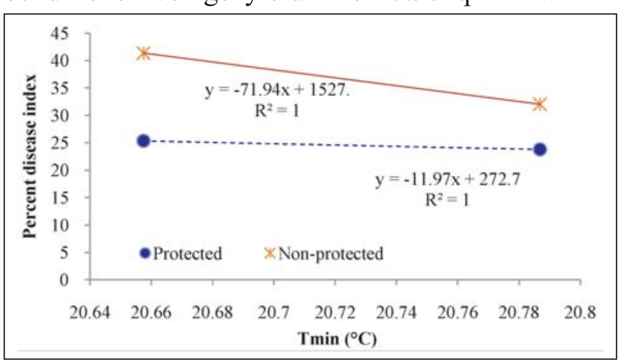

Figure 17. Effect of minimum temperature in the development of BLSB at Delhi

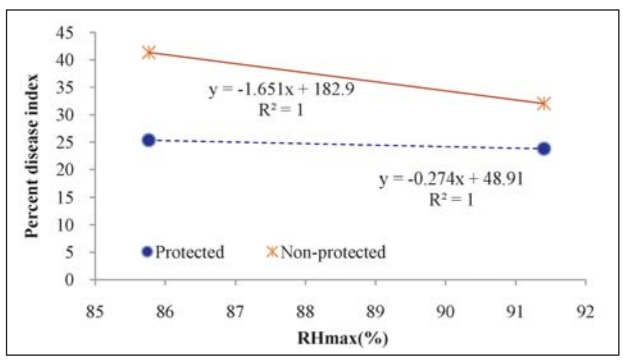

Figure 18. Effect of maximum relative humidity in the development of BLSB at Delhi

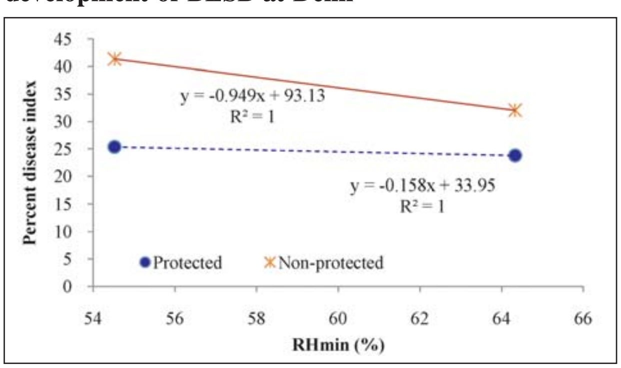

Figure 19. Effect of minimum relative humidity in the development of BLSB at Delhi

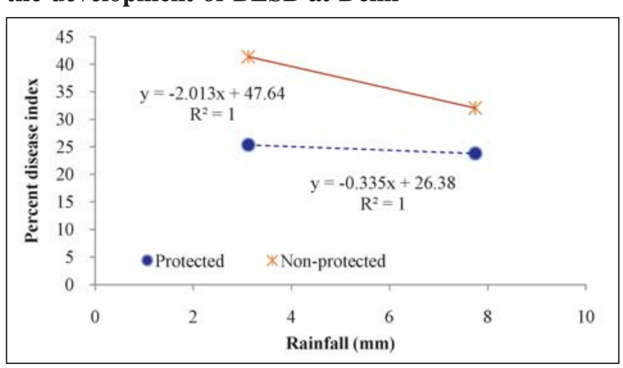

Figure 20. Effect of rainfall in the development of BLSB at Delhi

positively correlated (Figs 16-20) with all the weather parameters like Tmax, Tmin, RHmax, RHmin and rainfall (r= 1).

In Pantnagar, yield loss for BLSB was estimated from 2011 to 2013. Pooled data revealed that yield in protected plot was 47.48 q ha^{-1} with disease incidence of 23.8 whereas in non-protected plot yield was 37.69 q ha^{-1} with a disease incidence of 39.5 and avoidable yield loss due to BLSB was 20.62 per cent (Table 5). During the experimentation, disease incidence ranged from 27.7 (in 2012) to 46.6 per cent (in 2013) under non protected condition. In contrast under protected condition BLSB score was confined within narrow range from 23.3 (in 2013) to 27.7 (in 2012). The maize grain yield at Pantnagar was lower than Delhi location. Although reason is not clear, it is likely the differential influence of physical and environmental factors under both locations to which diseases could be a small factor to play diminishing role. This might also be due to another reason of natural occurrence of BLSB disease in more severe form at Pantnagar than the Delhi situation and consequently leads to more yield loss. Correlation of disease development with meteorological factors at Pantnagar revealed that the per cent disease intensity was highly and positively correlated (Figs 21-25) with the average maximum temperature (r = 0.968) followed by average maximum relative humidity (r = 0.937), The present investigation is in complete agreement with various workers who also previously reported that high humidity and high temperature were necessary and favourable for BLSB infection and

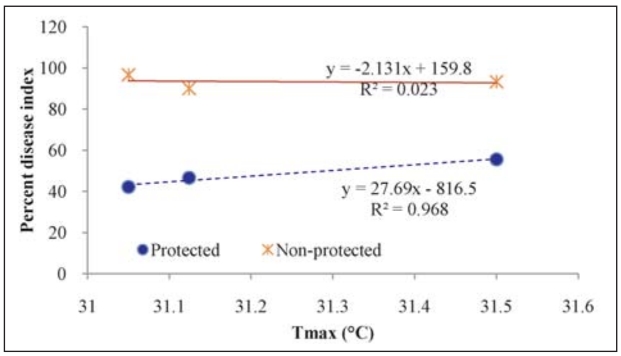

Figure 21. Effect of maximum temperature in the development of BLSB at Pantnagar

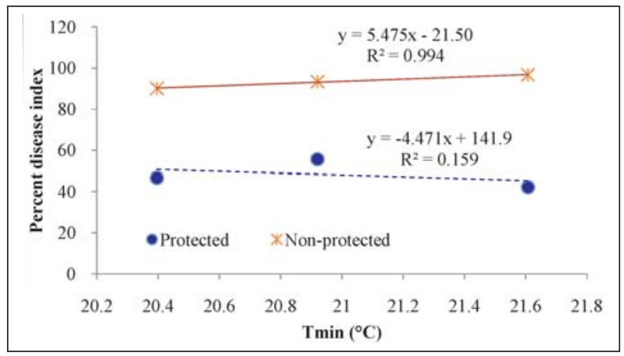

Figure 22. Effect of minimum temperature in the development of BLSB at Pantnagar

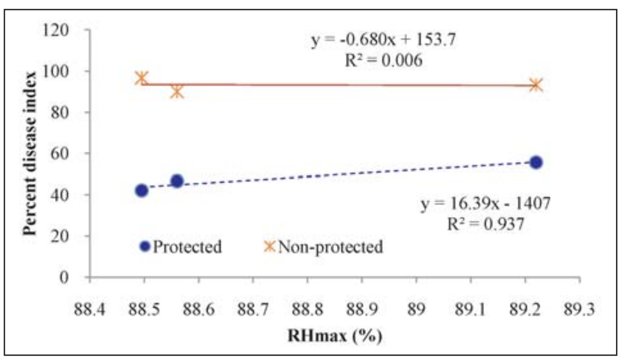

Figure 23. Effect of maximum relative humidity in the development of BLSB at Pantnagar

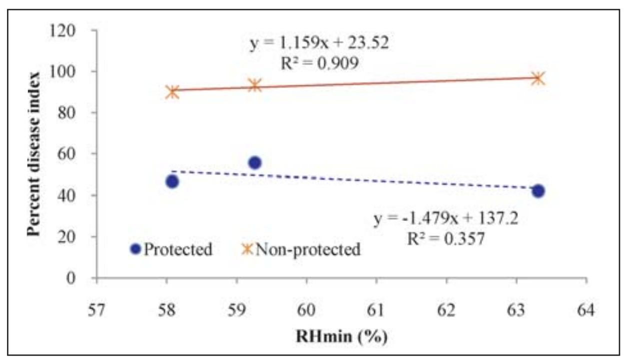

Figure 24. Effect of minimum relative humidity in the development of BLSB at Pantnagar

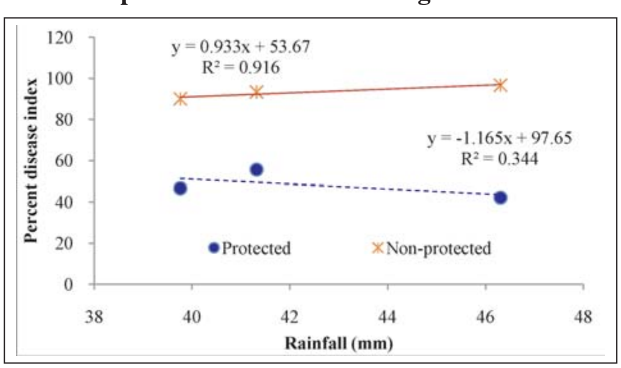

Figure 25. Effect of rainfall in the development of BLSB at Pantnagar

disease development, and rainfall does not show any significant relationship with the disease development in study period at Pantnagar.

In conclusion, meteorological factors played an important role in seasonal infection, distribution and disease build up. It is difficult to give a direct cause and effective relationship between any single factor and disease incidence because the impact of meteorological factors is usually compounded. This study clearly depicts the relationship between the weather factors and disease development. Additional research needs to determine the thresholds for yield loss associated with these two premier diseases of maize. Further work is also needed to determine whether there are critical times of leaf blight onset and to assess the risk of yield loss due to foliar diseases in maize.

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Compliance with ethical standards

Conflict of interest. The authors declare that they have no conflict of interest.

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