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Research Article

Relation between Growing Degree Days/Humid Thermal Index and Karnal Bunt Incidence in Central and Western Districts of Punjab

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ABSTRACT

Wheat is vulnerable to many diseases which reduce its yield and quality. Under changing climatic scenario, Karnal bunt in wheat is increasing in its occurrence and incidence. To know the effect of meteorological parameters on occurrence of Karnal bunt in wheat data was analysed for two zones viz. central and western zone of Punjab. Historical data of Karnal bunt incidence/infection of Ludhiana and Bathinda district along with meteorological data of corresponding years of both locations was collected and analysed. Maximum disease incidence was observed during 2010-11 in Bathinda and 2014-15 in Ludhiana district, while minimum disease incidence was recorded during 2016-17 in both districts. In the years with higher disease incidence, minimum temperature, morning relative humidity, evening relative humidity and total rainfall was higher than the years with lower disease incidence. Accumulated growing degree days (AGDD) and accumulated humid thermal indices (AHTI) were calculated for higher and lower disease years. Lower AGDD (962.1ºC day in Ludhiana and 908.95ºC day in Bathinda) were accumulated in the years with higher incidence of Karnal bunt from January to March and vice-versa. Similarly lower AHTI (985.1 in Ludhiana and 1418.2 in Bathinda) were accumulated in the years with higher incidence of Karnal bunt from January to March and vice versa. Higher accumulation of GDD restricts the activity of pathogen and suppresses the disease.

Key words: Wheat, Karnal bunt, Incidence, Infection, AGDD, AHTI

Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop during *rabi* season in Punjab. In India, it is second most important food crop after rice. Wheat is the staple food of more than 40% of human population. Being a thermo-sensitive crop, the productivity of wheat is largely determined by weather conditions that prevailed during the crop growing season. Adverse weather conditions like sudden increase in temperature during February-March, frequent western disturbances etc. reduce its yield. Wheat was grown on an area of 35.20 lakh hectares during 2018-19 in Punjab with the production of 182.62 lakh tonnes and average yield of 51.88 q/ha (Anonymous, 2021).

Wheat is vulnerable to attack of many diseases which reduce its yield and quality. Major diseases of wheat are yellow and brown rust, loose smut and flag smut, head scab, powdery mildew, Karnal bunt and black point which lead to reduction in quality of wheat. Among these diseases Karnal bunt is showing an increasing trend in severity as well as in prevalence in recent years. Karnal bunt is caused by a fungi *Tilletia indica* as reported by Mitra in 1931, but later on the fungi was transferred to the genus *Neovossia* as reported by Mundkar in 1940 on the

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basis of production of larger number of non-fusing primary sporidial (Nagarajan, 1997).

In Punjab, the disease was negligible during 2001 with average infection of 0.0008% and 95% samples were remained disease free followed by the years 2000 and 2004 when 84.9 and 82% samples were disease free and an infection in the state was 0.07 and 0.06% respectively. During 1996, only 29.6% samples were disease free with average infection of 0.64%. Amongst different districts, the disease was least in Patiala where 85% samples were Karnal bunt free followed by Amritsar with 81.12% disease free samples. Gurdaspur has emerged as major Karnal bunt prone district from 1994-2004 followed by Hoshiarpur with 56.95% average disease free samples. The variation in disease development was due to varietal susceptibility and environment conditions (Sharma *et al.,* 2004).

The establishment of the pathogen is highly dependent on suitable weather conditions. The infection gets established very well if the maximum temperature is in the range of 19-23°C and minimum 8-10°C, followed by high humidity by intermittent rains. These meteorological conditions prevail in the north-western region to cause more infection but absent in central and peninsular India (Gill *et al.,* 1993). Environmental factors play a major role in occurrence of Karnal bunt in epidemic form. Moderate temperature between 19-20°C, humidity greater than 70%, cloudiness or rainfall during anthesis favours the development of Karnal bunt. When there is overall 22±2ºC temperature, evening relative humidity > 48%, cloudiness more than 3.5 hour per day and rainy days more than 3 in last week of February and first week of March during boot to spike emergence stage, outbreak of Karnal bunt is supposed to occur. Number of rainy days at boot leaf stage is more important in the development of disease (Chahal, 2001).The prevailing weather conditions during the susceptibility period are responsible for observed variation in Karnal bunt incidence. The suitable temperature, high relative humidity, cloudy and rainy weather promote Karnal bunt development while dry conditions, high temperature and sunshine are unfavourable. Frequency of rainfall and humid thermal index (HTI) had a positive effect on Karnal bunt incidence. Its incidence in Hisar was more when HTI was ranged from 2.29 to 3.15 with rainfall for 3 to 7 days, these weather conditions resulted in more than 0.25% mean Karnal bunt infection in Karnal bunt positive year, whereas in case of Karnal bunt negative year HTI was either less than 2.29 or more than 3.15 and rainy days or frequency of February rainfall were less than 3 days (Singh and Karwasara, 2016). Maximum production of sporidia was observed at 20ºC and 25ºC, while at temperature higher or lower than the above limit abnormality in germ tube bearing plenty of macrosporidia occurred. Hence, affected the incidence and infection of Karnal bunt in different years. Different agroclimatic indices influence Karnal bunt development as higher accumulation of GDD hindered the activity of pathogen that lead to variability in Karnal bunt development (Kumar *et al.,* 2003). Anand *et al.* (2020) also concluded that agroclimatic indices can be used for prediction of pest attack in rice crop. Keeping all these aspects in view analysis of historical data of two districts located in different zones of state was conducted to evaluate the effect of growing degree days and humid thermal index on Karnal bunt incidence/infection.

Materials and Methods

For analysis of historical data, the meteorological data of the Ludhiana and Bathinda districts was collected from Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana. The data of Karnal bunt incidence from 2009-10 to 2019-20 of Ludhiana district and from 2010-11 to 2018-19 of Bathinda district were obtained from the Wheat Section, Department of Plant Breeding and Genetics, PAU, Ludhiana. The wheat grain samples were collected from the various grain markets in both the districts. Every year grain markets were surveyed and 15-30 samples were taken from each grain market. Samples of 500 g to 1000 g of grains from different heaps of wheat were collected randomly in paper bags. And the Karnal bunt incidence and infection was calculated from the collected samples of wheat.

From the data higher and lower disease years were identified for both locations. Weather conditions prevailing at both locations during higher and lower disease years were critically analysed. After evaluating the importance of temperature and humidity in Karnal bunt development, the accumulated growing degree days and accumulated humid thermal index from January to March (most susceptible period for Karnal bunt) were worked out by using following formulas:

Accumulated Growing Degree Day (AGDD)

Accumulated Growing degree days were calculated by using the following formula:

$$AGDD = \sum_{i=1}^{n} \frac{T_{max} + T_{min}}{2} - T_b$$

Where,

AGDD = Accumulated Growing Degree Days (°C days)

T_{max} = Maximum temperature (°C) of the day

T_{min} = Minimum temperature (°C) of the day

T_b = Base temperature (5°C) (Slafer and Savin, 1991)

Accumulated Humid Thermal Index (AHTI)

The Accumulated humid thermal index was calculated by the using the following formula:

$$AHTI = \sum_{i=1}^{n} \frac{\text{Morning relative humidity}}{\text{Minimum temperature}}$$

Where,

AHTI= Accumulated Humid Thermal Index

i = 1 to n [Time interval (days)]

After calculating these indices, the relationships were developed between these indices and Karnal bunt incidence/infection for both districts of state.

Results and Discussion

Average disease incidence and average disease infection

The percent infected samples and average disease infection of Karnal bunt in Ludhiana district from 2009-10 to 2019-20 is presented in Fig. 1. Maximum infected samples (98.4%) were recorded in year 2014-15 and minimum (1.59%) in the year 2016-17. In different years, infected samples varied significantly in incidence and infection. Maximum disease infection (2.66%) was observed in year 2014-15 and 0.005% in 2016-17. The year to year difference in percent infected samples and average

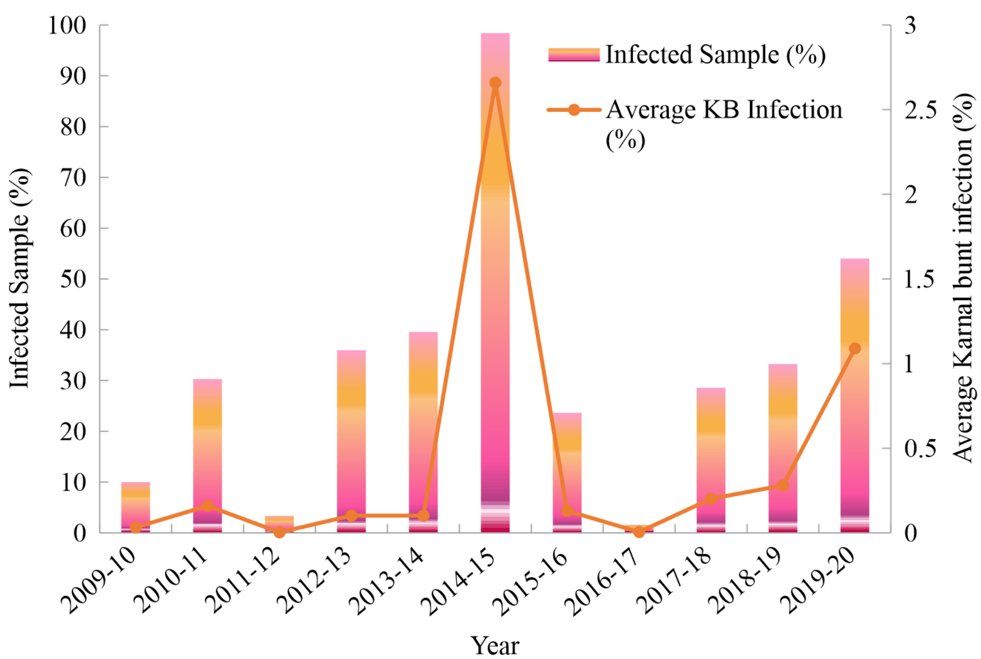

Fig. 1. Infected samples (%) and average disease infection (%) of Karnal bunt in Ludhiana district (2009-10 to 2019-20)

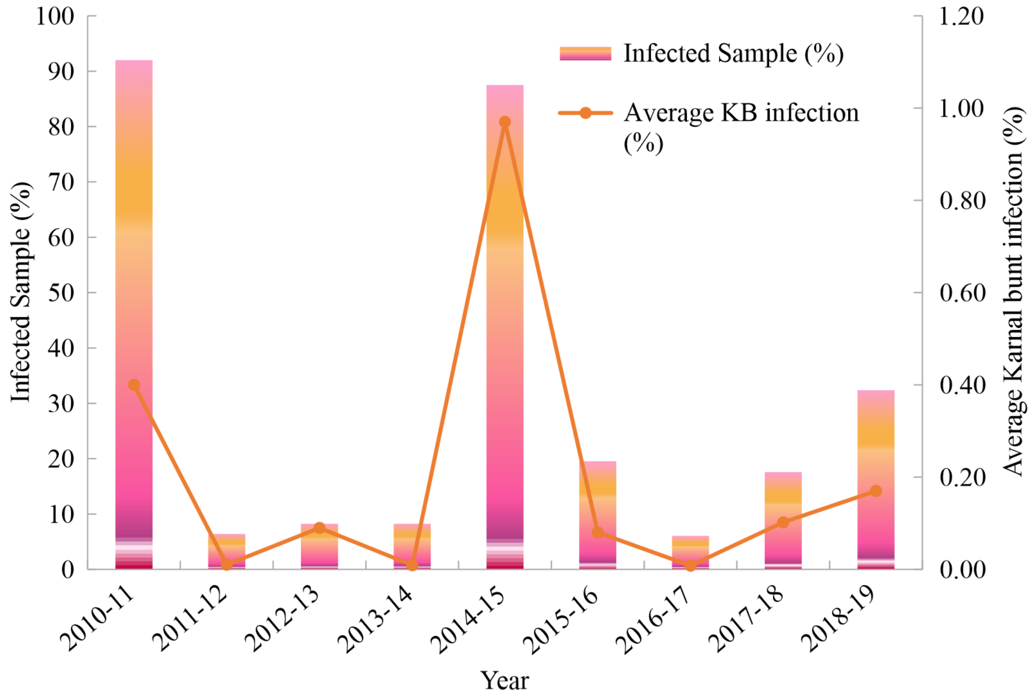

Fig. 2. Infected samples (%) and average disease infection (%) of Karnal bunt in Bathinda district (2010-11 to 2018-19)

infection of Karnal bunt is mainly due to variability in weather conditions prevailed during particular year.

The percent infected samples and average disease infection of Karnal bunt in Bathinda district from 2010-11 to 2018-19 is presented in Fig. 2. Maximum infected samples were recorded in year 2010-11 and minimum in the year 2016-17. During year 2010-11, 92% infected samples were recorded, whereas during 2016-17 only 6.05% collected samples were infected. Weather conditions play important role in year to year variations in infected samples and average disease infection. Similarly, Sandhu and Dhaliwal (2017) reported that wheat diseases are influenced by prevailing weather conditions.

Weather conditions from January to March during higher and lower disease incidence/ infection years

The analysis of Karnal bunt data of Ludhiana district indicated that year 2014-15 recorded maximum disease incidence and infection whereas year 2016-17 recorded minimum Karnal bunt incidence and infection. So, average weather conditions prevailed from January to March during both these year were evaluated and presented in Fig. 3. Average maximum temperature was 21.1ºC and 22.9ºC in 2014-15 and 2016-17, respectively. Average minimum temperature was 10.3ºC and 9.8ºC in 2014-15 and 2016-17, respectively. Average morning and evening relative humidity was 94% and 65% in year 2014-15 and was 91% and 48% in 2016-17. Total rainfall was 147.8 mm and 92 mm in year 2014-15 and 2016-17, respectively. Average sunshine hours were 5.5 and 6.9 in year 2014-15 and 2016-17, respectively. In the year with higher disease incidence, minimum temperature, evening relative humidity and total rainfall was exceptionally higher than the years with lower disease incidence. Similarly, in the years with higher disease infection, evening relative humidity and rainfall was higher than the years with lower disease infection. In 2014-15, higher disease incidence as well as higher disease infection was recorded, but in 2016-17 despite of lower disease incidence, lowest infection was not recorded. The reason behind this may be occurrence and amount of rainfall. Lowest infection was recorded in year 2011-12 in spite of high percentage

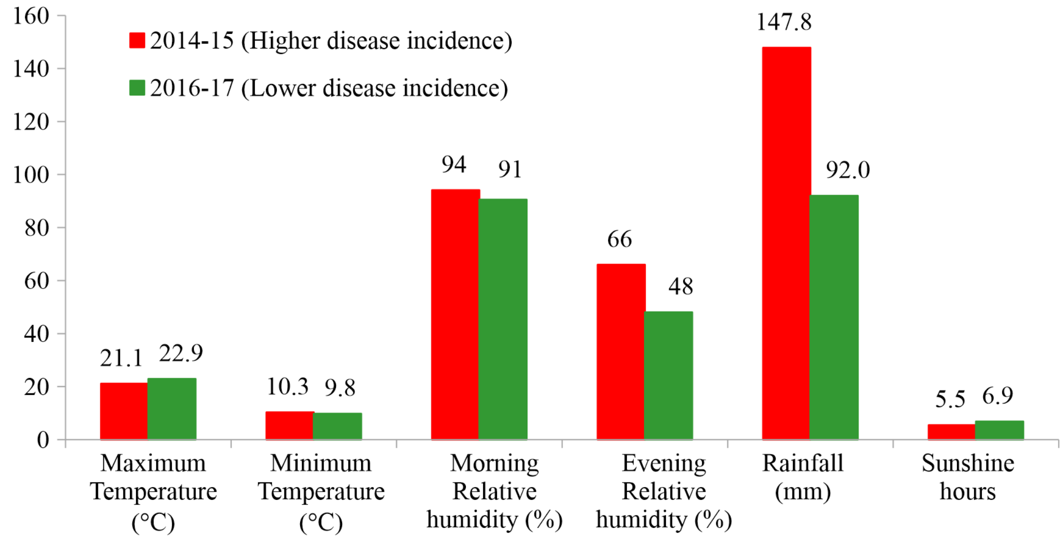

Fig. 3. Average weather conditions from January to March during higher and lower disease incidence/infection years in Ludhiana

of infected samples, because in this year no single drop of rainfall was received during the entire month of February and March. So it can be concluded that infection of Karnal bunt is associated with incidence of the disease and vice-versa. But sometimes due to specific change in any weather parameter like amount of rainfall changes this relationship and influences disease infection. Jain and Sandhu (2019) revealed that the meteorological parameters can be used to develop weather based disease prediction model which can be very helpful for issuing disease forewarning so that necessary precautions can be taken in order to manage disease incidence.

Average weather conditions prevailed from January to March in year with higher disease incidence (2010-11) and lower disease incidence (2016-17) in Bathinda are presented in Fig. 4. Average maximum temperature was 21.7ºC and 23.7ºC in 2010-11 and 2016-17, respectively. Average minimum temperature was 8.5ºC and 8.6ºC in 2014-15 and 2016-17, respectively. Average morning and evening relative humidity was 94 and 52% in year 2010-11 and was 83 and 51% in 2016-17. Total rainfall was 37.6 and 9.5 mm in year 2010-11 and 2016-17, respectively. Average wind speed was 3.2 and 2.8 in year 2010-11 and 2016-17, respectively. Average weather conditions in the year of higher Karnal bunt infection (2014-15) and lower Karnal bunt infection (2016-17) are presented in Fig. 5. Average maximum temperature was 21.2ºC and 23.7ºC in 2014-15 and 2016-17, respectively. Average minimum temperature was 9.8ºC and 8.6ºC in 2014-15 and 2016-17, respectively. Average morning relative humidity was 95% and 83% in 2014-15 and 2016-17, respectively. Evening relative humidity was 59% and 51% in year 2014-15 and 2016-17, respectively. Total rainfall was 136.2 mm in 2014-15 and 9.5 mm in 2016-17. Average wind speed was 3.5 and 2.8 in 2014-15 and 2016-17, respectively. From the weather data it is evident that morning relative humidity and rainfall made difference in Karnal bunt development among different years in Bathinda district. Singh *et al.* (2018) observed that rainfall and number of rainy days along with minimum temperature during the 6th SMW were the most important weather parameters indicating favorable role in the development of Karnal bunt disease. Wind speed was also important during this week for the transfer of primary sporidia from soil to leaf. Rainfall along with morning and evening relative humidity during 9th SMW indicated favorable role in further multiplication of secondary sporidia. Rainfall and rainy day during 10th, 11th and 12th standard meteorological week helped in multi-plication of Karnal bunt disease in wheat. The 68 per cent variability in occurrence of Karnal bunt disease in Karnal zone was observed in relation to weather parameter.

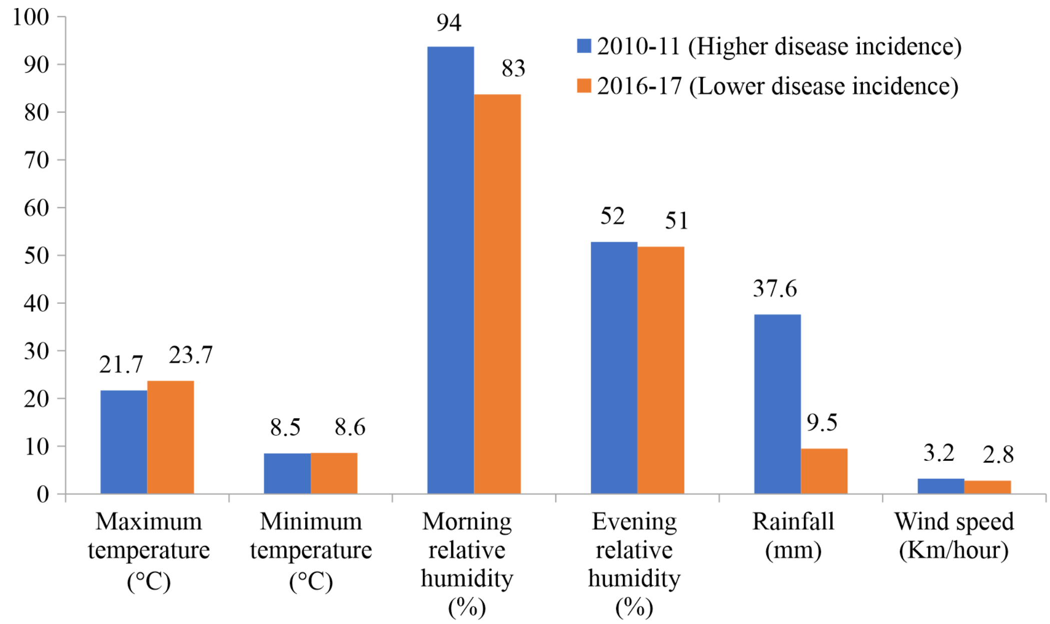

Fig. 4. Average weather conditions from January to March during higher and lower disease incidence years in Bathinda

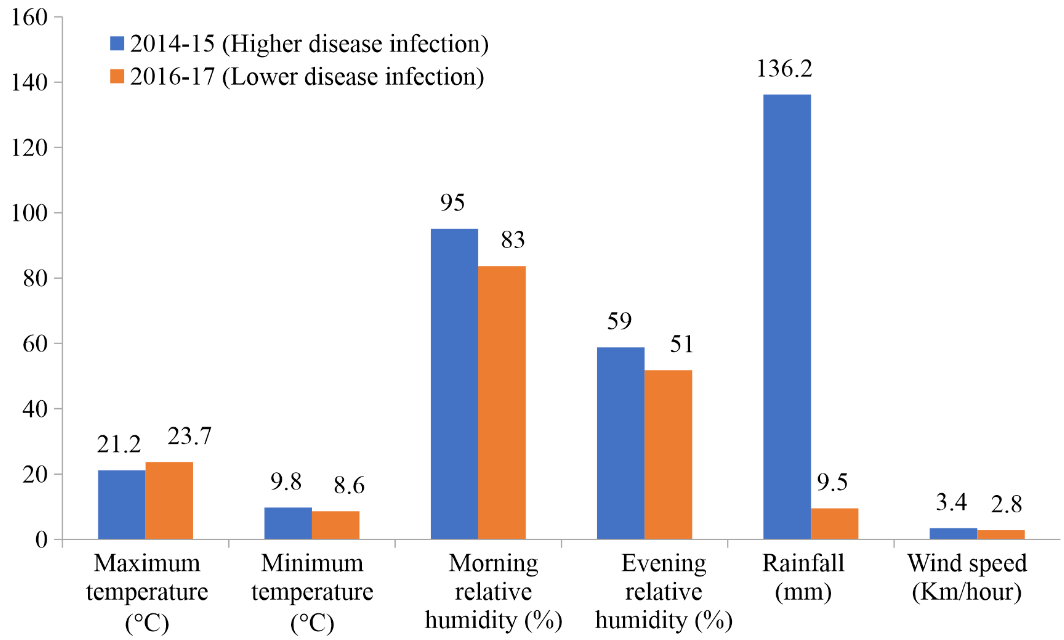

Fig. 5. Average weather conditions from January to March during higher and lower disease infection year in Bathinda

Relation between accumulated growing degree days and Karnal bunt incidence

Accumulated growing degree days (AGDD) were calculated for the years with higher and lower disease incidence as well disease infection of Karnal bunt to assess the role of heat units in the development of disease as every pathogen requires specific amount of heat units to complete its life cycle. So, growing degree days accumulated from January to March during the year 2014-15 (higher disease incidence/infection) and 2016-17 (lower disease incidence/infection) were calculated. It was observed that more growing degree days were accumulated in year with lower Karnal bunt incidence as compared to year with higher disease incidence (Fig. 6). During 2016-17, it was 1021.3ºC day from January to March whereas, during 2014-15, it was only 962.1ºC day. Higher AGDD was due to high temperature during lower disease incidence year which hampered the activity of pathogen and resulted in lower disease incidence.

It was observed that in the years with more than 30% disease incidence, the accumulated GDD were in the range of 911.2-962.1ºC day. AGDD calculated for 2010-11, 2012-13, 2013-14, 2014-15, 2018-19 and 2019-20 was 951.4, 953.5, 911.2, 962.1, 925.5 and 952.3ºC day respectively. In case of lower disease incidence (<10%), it was in the range of 1021.3-1058.7ºC day with exception of year 2011-12 in which accumulated growing degree was only 871.4ºC day. This variability in accumulation of GDD and disease incidence was due to lesser rainfall. The low incidence (3.36%) of Karnal bunt in 2011-12 despite of low accumulated GDD, which actually favours the high disease incidence, was due to very low rainfall from January to March. The total rainfall was 52.6 mm which occurred only in the month of January and there was no rainfall during the entire months of February and March. No rainfall during critical period of disease development resulted in low disease incidence. During the year with higher disease infection less growing degree days were accumulated as compared to lower disease infection year, results were similar to pattern of disease incidence years. So, it can be concluded that more growing degree days are associated with low disease incidence as well as low disease infection. Kaur *et al.* (2007) reported that survival of sporidial colonies in the wheat field was negatively correlated with GDD and temperature and was positively correlated with relative humidity during heading of wheat crop.

Accumulated growing degree days were calculated from January to March, for Bathinda district, for the years with higher and lower incidence and infection of Karnal bunt. The results were same as they were obtained for Ludhiana district. It was found that less growing degree days were accumulated from January to March in year (2010-11) with higher incidence of Karnal bunt and more growing degree days were accumulated in year (2016-17) with lower disease incidence (Fig.7). During 2010-11, AGDD was 909.0ºC day and 1003.8ºC day in 2016-17. Higher maximum and minimum temperature in 2016-17 led to higher accumulation of GDD and higher temperature suppressed the activity of pathogen and resulted in lower disease incidence. It was 903.3ºC day in 2018-

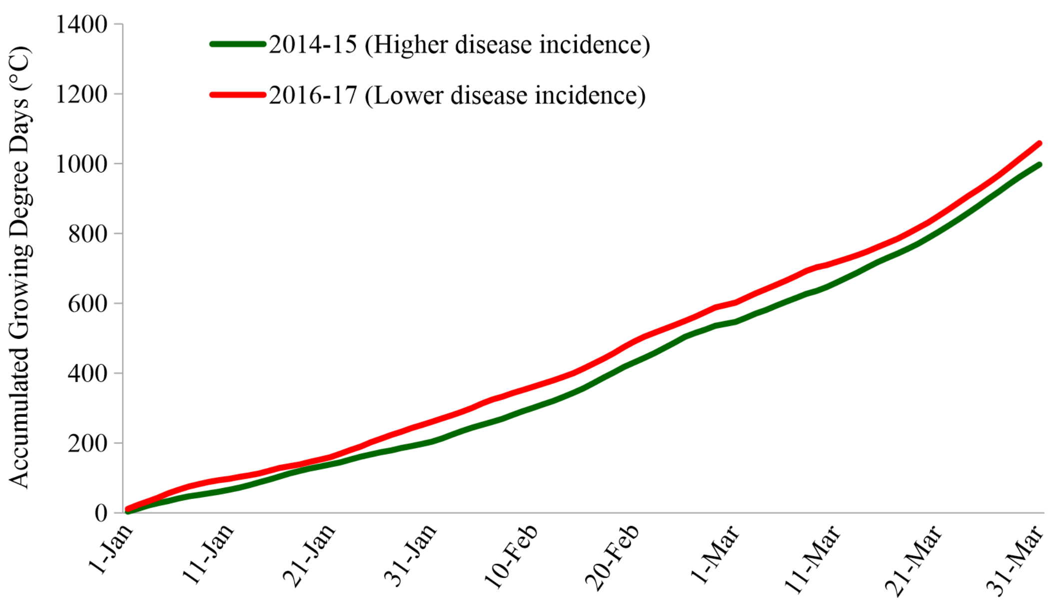

Fig. 6. Accumulated Growing degree days (AGDD) during higher and lower Karnal bunt incidence/infection year in Ludhiana

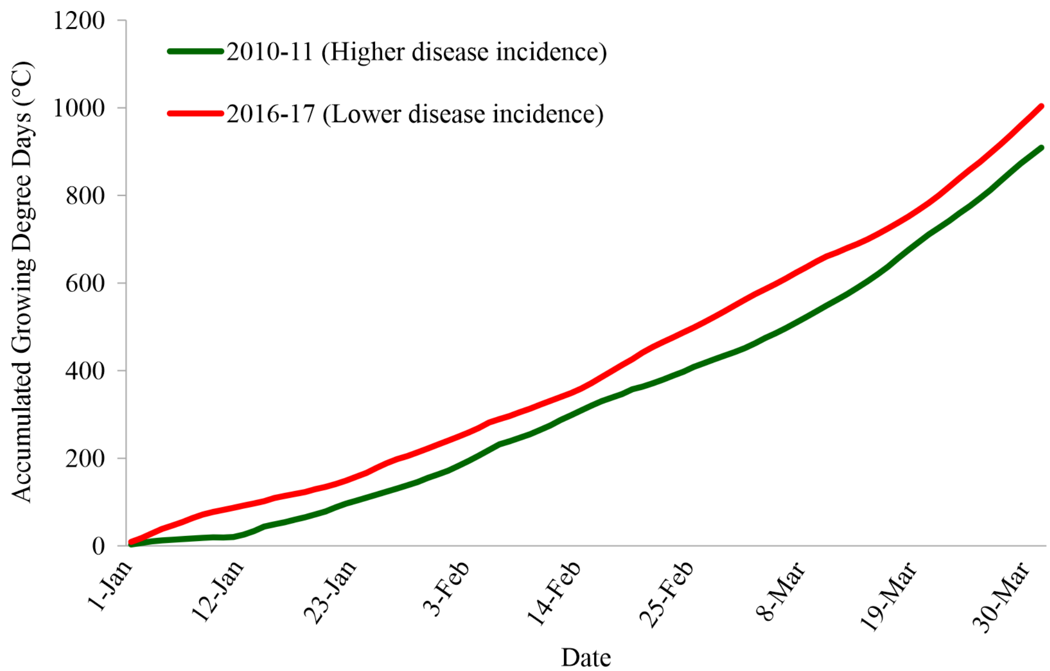

Fig. 7. Accumulated Growing degree days (AGDD) during higher and lower Karnal bunt incidence years in Bathinda

19 during which 32.4% infected samples were reported and 1009.5ºC day in 2017-18 during which 17.6% infected samples were observed.

Similarly higher GDD was accumulated in the year (2016-17) with lower disease infection and lower was accumulated in the year (2014-15) with higher disease infection. It was 942.3ºC day in 2014-15 and 1003.8ºC day in 2016-17 (Fig. 8). It was 909.0ºC day in 2010-11 during which 0.40% disease infection was observed and 1009.5ºC day in 2017-18 during which 0.17% Karnal bunt infection was reported. Kaur and Singh (2000) concluded that quick ripening of grains due to rise in temperature resulted in lower Karnal bunt incidence even in endemic areas. They further said that severe incidence of Karnal bunt will be expected only when from heading to maturity of wheat, the required GDD is spread over more number of days.

Relation between accumulated humid thermal index and Karnal bunt

Humid thermal index describes the combined effect of relative humidity and temperature on the development of disease. Number of researchers developed the predictive models of Karnal bunt based on humid thermal index and some differentiated the regions of high and low Karnal bunt incidence based on the value of it. So keeping in view the importance of humid thermal indices, accumulated humid thermal index was calculated from January to March, by dividing the morning relative humidity with minimum temperature, for the years with high and low Karnal bunt incidence and infection. The accumulated HTI for the years with higher (2014-15) and lower (2016-17) incidence/infection of Karnal bunt is presented in Fig. 9. It was observed that accumulated HTI was lesser in higher Karnal bunt incidence year and more in lower Karnal bunt year. It was 985.1 in 2014-15 and 1065.5 in year 2016-17. It was 1534.0 in year 2011-12 which had 3.36% disease incidence. Jhorar *et al.* (1992) reported that the conditions for development of Karnal bunt became unfavourable when HTI values were too high. They gave a range of 2.2-3.3 of humid thermal index under which severe disease develop. The higher HTI values are the result of high humidity and low temperature. Singh and Karwasa, (2016) reported that HTI predictive model become more correct, if the rainfall during the susceptible crop

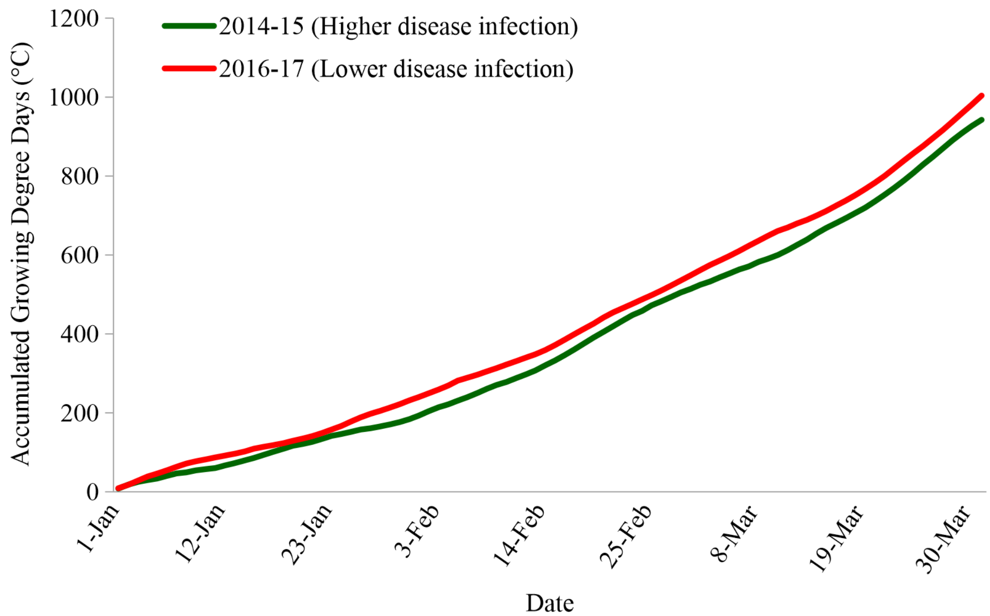

Fig. 8. Accumulated Growing degree days (AGDD) during higher and lower Karnal bunt infection years in Bathinda

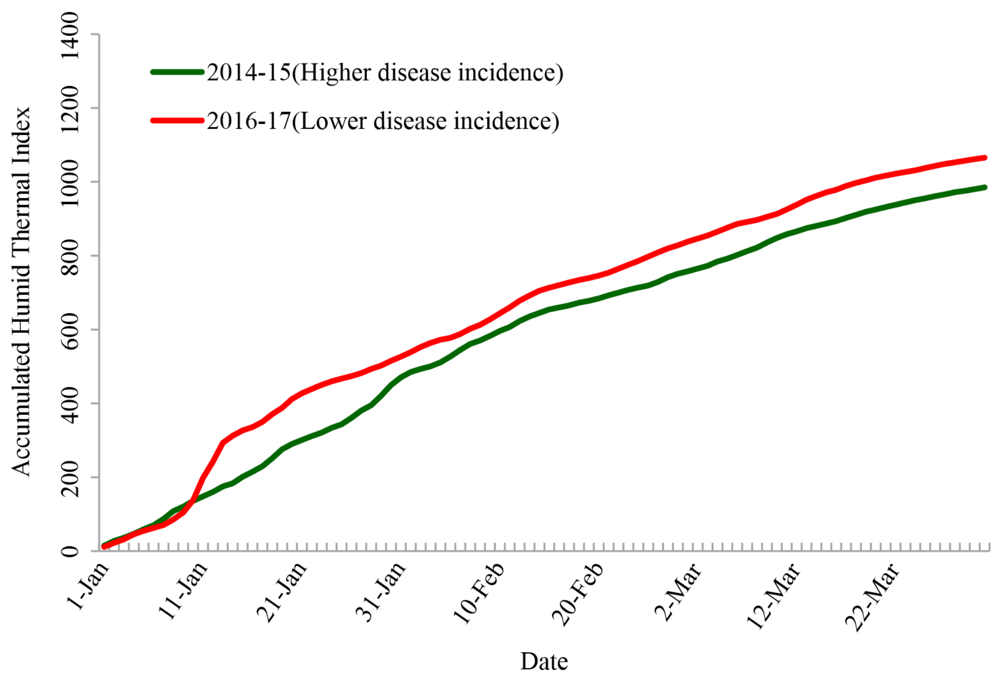

Fig. 9. Accumulated humid thermal index (AHTI) during higher and lower Karnal bunt incidence/infection year in Ludhiana

growth period is also taken into account. Allen *et al.* (2009) suggested the incorporation of other parameters like rainfall, irrigation and duration of susceptible crop growth stage to increase the predictive efficiency of HTI models.

The accumulated HTI for the years with higher (2010-11) and lower (2013-14) incidence of Karnal bunt is presented in Fig.10. The trends similar to Ludhiana district were observed in case of Bathinda district. It was observed that accumulated HTI was

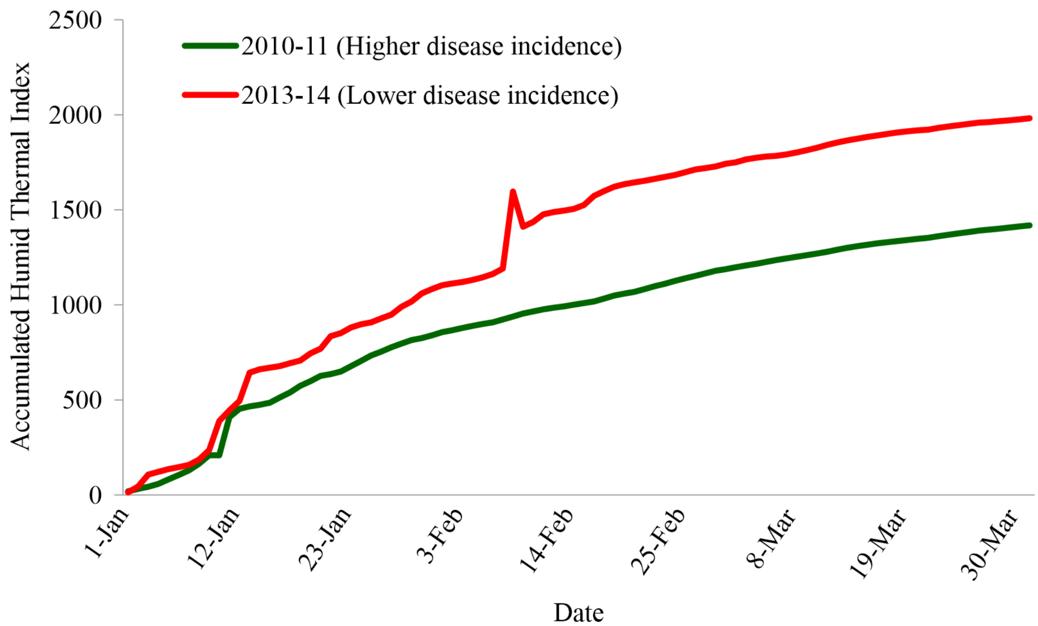

Fig. 10. Accumulated humid thermal index (AHTI) during higher and lower Karnal bunt incidence years in Bathinda

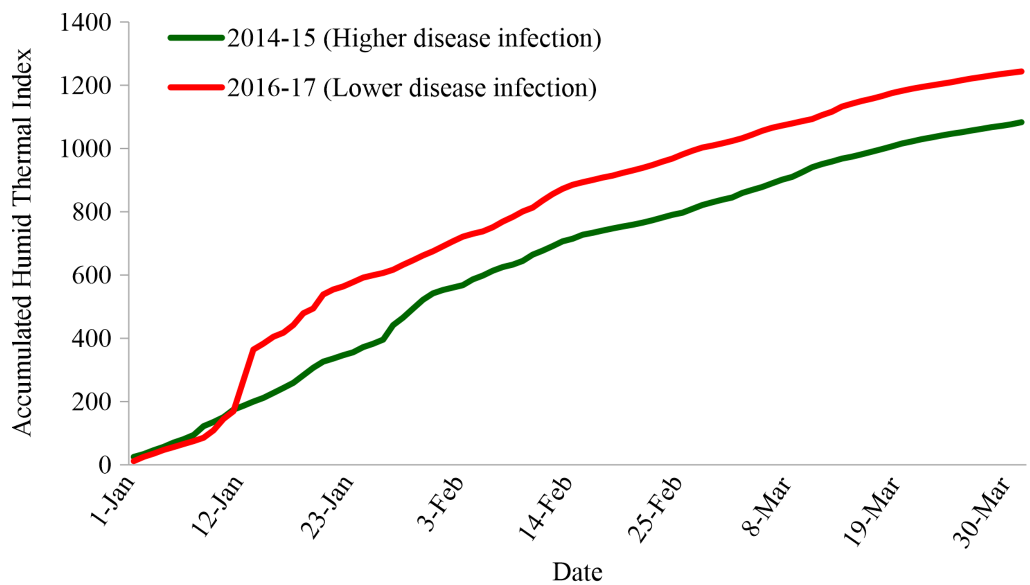

Fig. 11. Accumulated humid thermal index (AHTI) during higher and lower Karnal bunt infection years in Bathinda

lower in higher Karnal bunt incidence year and was higher in lower Karnal bunt incidence year. It was 1418.2 in 2010-11 (92% infected samples) and 1987.6 in 2013-14 (8.24% infected samples). Similar pattern of AHTI was observed in case of Karnal bunt infection (Fig.11). Higher AHTI was accumulated in year with lower disease infection and vice versa. It was 1083.2 in 2014-15 (0.97% average infection) and 1245.6 in 2016-17 (0.008 % average infection). High morning relative humidity and high minimum temperature in higher Karnal bunt incidence and infection year led to accumulation of low humid thermal index. As it is known that high morning humidity and high minimum temperature favours the development of Karnal bunt, thus more incidence and infection of Karnal bunt was observed in years with lower AHTI.

Conclusion

Accumulated growing degree days (AGDD) and accumulated humid thermal index (AHTI) was lower in the years with high incidence and infection of Karnal bunt in Ludhiana as well as Bathinda district of Punjab. From this analysis it has been identified that rainfall is the most important weather parameter for Karnal bunt infection because Karnal bunt infection was very less or negligible in the year which received lower rainfall during February and March. Hence by calculating agroclimatic indices up to March or mid-March and amount of rainfall during February and March, incidence of Karnal bunt in wheat can be assessed in advance to take necessary measurements to maintain quality of wheat seed.

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