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Research Article

Assessment of Weather-Disease-Yield Interactions in Wheat under Central Punjab

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ABSTRACT

Field experiments on wheat were conducted at Punjab Agricultural University, Ludhiana during *rabi* 2012-13 and 2013-14. In the first experiment, wheat varieties HD 2967, PBW 550 and PBW 343 were sown under three row-pacing viz. 15, 22.5 and 30 cm under sprayed and unsprayed conditions. In the second experiment, wheat varieties HD 2967, PBW 550 and PBW 343 were sown under two row directions viz. north-south (N-S) and east-west (E-W) under sprayed and unsprayed conditions. The incidence of yellow rust was recorded at weekly intervals starting from first appearance of yellow rust symptoms till the maturity of crop. Peak disease incidence was influenced by crop geometry and wheat varieties. Among different varieties, HD 2967 showed a minimum and PBW 343 recorded a maximum yield loss due to incidence of yellow rust during both the crop seasons. The yield losses due to disease incidence recorded were maximum in 15 cm row-spacing (39%) and the least was recorded in wider row-spacing of 30 cm (12.3%). Among different row directions, yield losses were higher (18%) in N-S compared to E-W direction (15.7%). Relationships developed between yellow rust incidence and grain yield was highly significant in different row spacing (R^2 =0.85) and row direction (R^2 =0.88).

Key words: Row spacing, Row direction, Wheat, Yellow rust, Yield loss

Introduction

Wheat (*Triticum aestivum* L. Emend Feori and Paul) is the second most important *rabi* cereal crop in India after rice, and is extensively cultivated in North-Western and Central zones. In Punjab, during 2013-2014, it was grown on an area of 35.12 lakh ha with production of 176.20 lakh tonnes and productivity of 50.17 q ha^{-1} (Anonymous, 2014). Wheat is a photo-insensitive and thermo-sensitive long day plant and its crop season are limited by the onset and end of favourable temperature regimes. The crop requires cool climate during the early part of its growth and its grain yield and quality are influenced by temperature regimes during different phases of crop growth. The warmer temperature within the growing season shortens the total crop duration. Higher temperature during early vegetative phase results in sparse tillering, poor vegetative growth, early heading, and during grain filling phase leads to shrivelled grains and forced maturity (Reddy, 2006). A mean daily temperature of 15-20^{o}C is optimum for crop growth, development and flowering of wheat crop.

Wheat crop is attacked by a large number of diseases which appear in epidemic proportions and causing loss in yield and quality. Plant diseases affect 55% of the global wheat growing area, causing an estimated loss of 20 million tonnes of wheat per annum (Kosina *et al.,* 2007).

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The stripe or yellow rust caused by *Puccinia striiformis westend.* f.sp. *tritici* is the major disease causing huge losses to the wheat productivity in north-western of India. Yellow rust appeared in severe form in plain areas of Jammu and Kashmir, foot hills regions of Punjab and Himachal Pradesh and some parts of Haryana, Tarai region of Uttarakhand hills during 2008-09, 2009-20 and 2010-11 (Pannu *et al.,* 2010). This disease remains a major constraint to wheat production in this region.

Microclimate of a crop varies from top to bottom of a canopy, and its study is necessary for modifications in order manage the climate change impacts (Kingra and Kaur, 2017). The incidence percentage and severity index of yellow rust and powdery mildew were higher under flat-planted than bed-planted crop under Punjab conditions. Under bed-planted crop due to more circulation of air, the relative humidity remained lower than flat-planted crop so the incidence of disease was recorded low under bed-planted crop (Kaur, 2012). Microclimate also influences disease incidence and severity, and so modification of microclimate is helpful to manage diseases. Microclimate of crop with dense canopy favours the growth and development of the pathogen that requires high level of moisture. So wider row-spacing was observed as best option to manage disease severity of such disease which increased with higher relative humidity within crop (Haware *et al.,* 1997). Afzal *et al.* (2007) revealed that a direct linkage exists between the disease level and the yield loss in the most commonly cultivated wheat varieties. Keeping these in view, the study was planned to assess the affect of crop geometry on incidence of yellow rust and yield losses in grain yield due to yellow rust under different row spacing and row direction.

Materials and Methods

The field experiments on wheat were conducted at the Research Farm, Department of Climate Change and Agricultural Meteorology during *rabi* seasons of 2012-13 and 2013-14. In first experiment wheat varieties HD 2967, PBW 550 and PBW 343 were sown in three row spacing viz. 15 cm, 22.5 cm and 30 cm under sprayed and unsprayed conditions. In second experiment wheat varieties HD 2967, PBW 550 and PBW 343 were sown with two row directions viz. North-South (N-S) and East-West (E-W) under sprayed and unsprayed conditions. The crop was raised as per recommendations of Punjab Agricultural University.

The peak disease incidence was recorded from any of the 50 randomly selected plants in a plot and percent disease incidence was calculated by using following formulae:

$$\text{Disease incidence (\%)} = \frac{\text{No. of diseased plants}}{\text{Total no. of plants examined}} \times 100$$

Daily observations on maximum and minimum temperature, morning relative humidity, rainfall were recorded at the Agrometeorological Observatory; and foggy and frost days were observed visually during the disease incidence period. Weekly meteorological data of both crop seasons were analysed and compared with normal weather data. Grain yield was recorded at the time of harvest in all the treatments of experiment. Percent yield losses due to yellow rust were calculated by using following formulae:

$$\text{Yield losses (\%)} = \frac{\text{Grain yield of sprayed plot - Grain yield of unsprayed plot}}{\text{Grain yield of sprayed plot}} \times 100$$

The relationships were developed between yellow rust incidence and grain yield.

Results and Discussion

Meteorological parameters during disease incidence period

Maximum temperature remained below normal during 2012-13 and 2013-14 from 1st to 13th standard meteorological week (SMW) (Fig.1) except during 5th, 10th, 11th and 12th SMW of 2012-13 where it was above normal. During 2012-13, maximum temperature remained higher than 2013-14 during 1st to 13th SMW. As temperature plays an important role in disease occurrence and development, this higher temperature during 2012-13 favoured higher disease incidence compared to that in year 2013-14. There was a

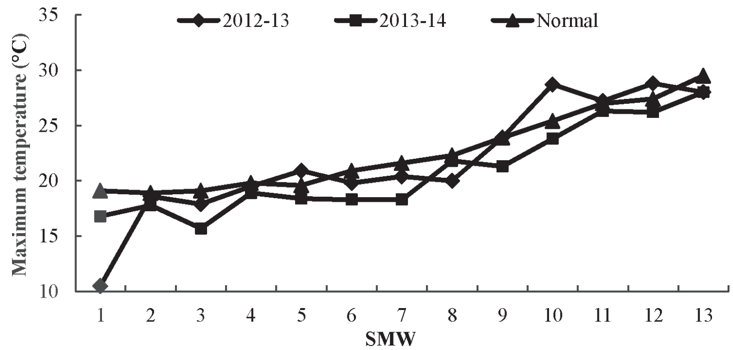

Fig. 1. Comparison of maximum temperature during disease development period in 2012-13 and 2013-14

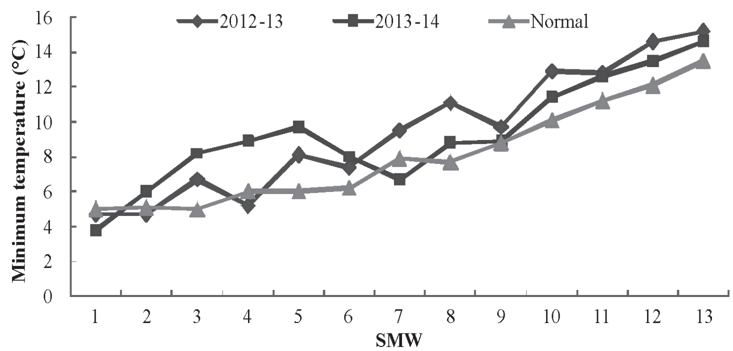

Fig. 2. Comparison of minimum temperature during disease development period in 2012-13 and 2013-14

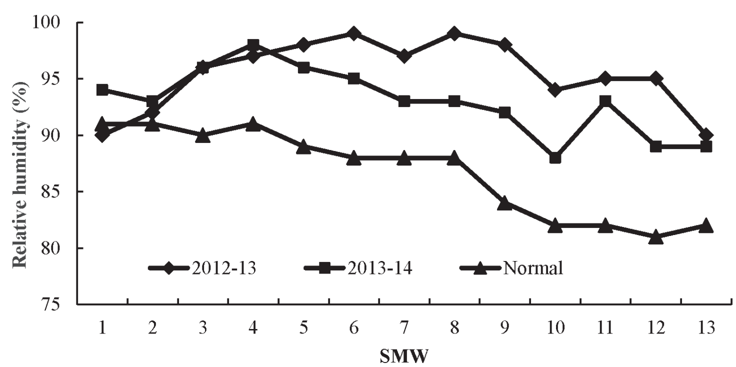

Fig. 3. Comparison of morning relative humidity during disease development period in 2012-13 and 2013-14

rapid spread of disease between 5th and 12th SMW when the maximum temperature ranged from 20.9°C to 28.8°C during 2012-13 and 18.4°C to 26.2°C during 2013-14. Minimum temperature remained higher than normal minimum temperature. Minimum temperature was higher in 2013-14 than in 2012-13 up to 6th SMW (Fig. 2). During peak disease development period i.e., 5th to 12th SMW, minimum temperature was in the range of 8.1°C to 14.6°C in 2012-13 and 9.7°C to 13.5 °C in 2013-14. Higher range of minimum temperature than the normal (especially during 7th and 8th SMW) favoured the yellow rust development. Morning relative humidity ranged between 90 to 99 per cent and 81 to 98 per cent during 2012-13 and 2013-14, respectively from 1st to 13th SMW. During most of the period, morning relative humidity remained higher than normal as presented in Fig. 3. The higher morning relative humidity during 2012-13 compared to 2013-14 was favourable for the disease development. Milus and Seyran (2004) revealed that stripe rust caused by the new isolates tends to develop faster than the old isolates at relatively

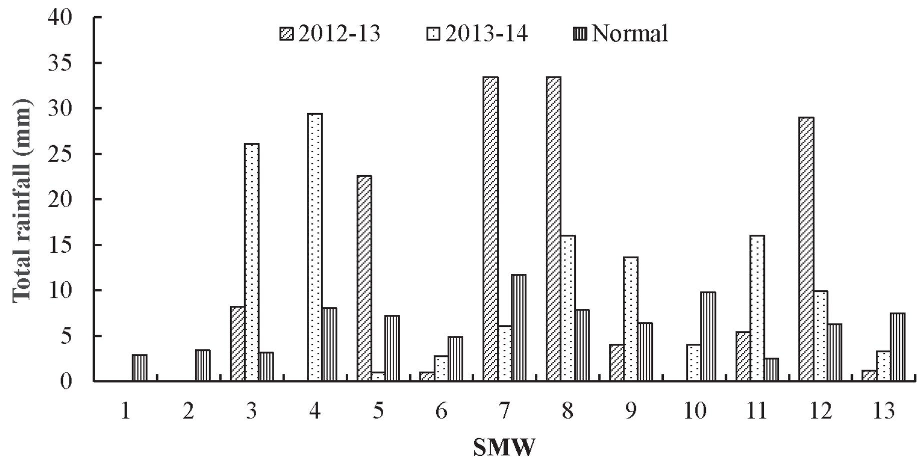

Fig. 4. Comparison of total rainfall during disease development period in 2012-13 and 2013-14

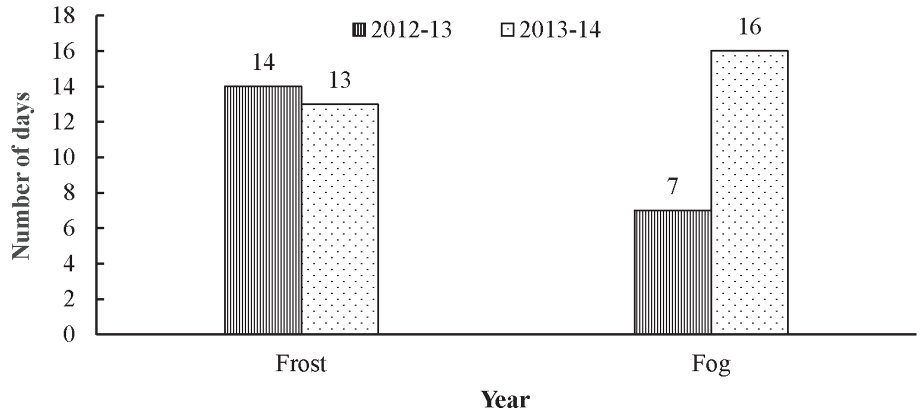

Fig. 5. Comparison of foggy and frost days during 2012-13 and 2013-14

high temperatures. Infection efficiency of rust pathogen is affected by meteorological parameters. Temperature and humidity play key role in disease infestation. High humidity for 4 to 6 h at 10 to 15°C increases infestation. Infestation seldom occurs at <2°C and ceases at >23°C (Murray *et al.,* 2005). The rainfall of 138 and 128 mm was recorded from 1st to 13th standard meteorological week (SMW) during 2012-13 and 2013-14, respectively. Amount of rainfall received during two crop seasons was almost same but the peak disease development period was effected by amount of rainfall (Fig. 4). During 5th to 12th SMW *i.e.*, in peak disease development period, only 69 mm rainfall was received during 2013-14 as compared to 128 mm rainfall in 2012-13. Thus higher amount of rainfall increased the humidity and favoured the pathogen to grow during 2012-13. During both the crop seasons, it was observed that frost days were almost same (Fig. 5). Number of foggy days was higher during 2013-14 compared to 2012-13. Fog plays an important role in yellow rust incidence as fog reduces the ability of yellow rust pustules to spread.

Disease incidence under different crop geometry

Yellow rust incidence was observed in different treatments. Among the varieties, HD 2967 was highly resistant to yellow rust compared to PBW 550 and PBW 343. In HD 2967 var., traces of powdery mildew were recorded in 15 cm row-spacing in both the years. The per cent yellow rust incidence was higher in PBW 343 compared to PBW 550 during both the seasons, as PBW 343 is more susceptible to yellow rust than PBW 550. Among different row-spacings,

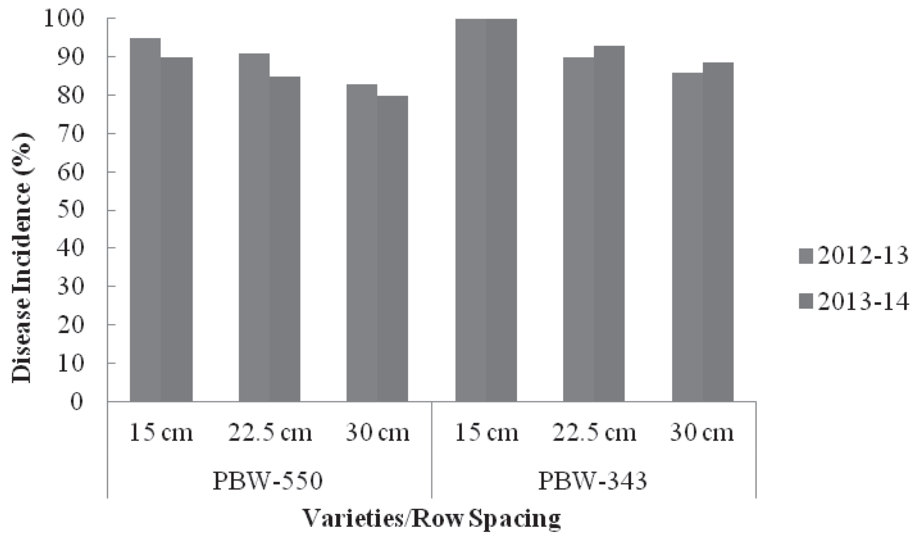

Fig. 6. Percent disease incidence under different row spacing

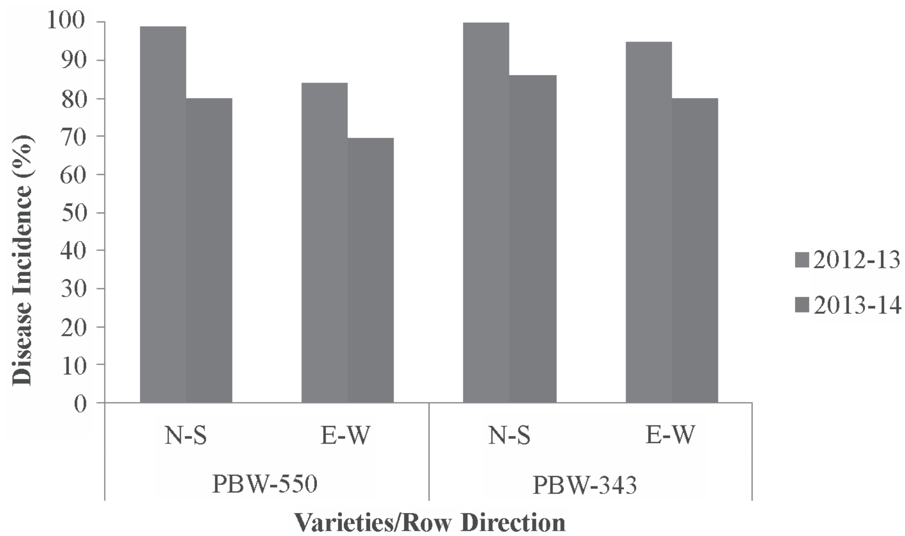

Fig. 7. Percent disease incidence under different row direction

disease incidence was higher in 15 cm spacing followed by 22.5 and 30 cm row spacings (Fig. 6). This could be due to congenial conditions in 15 cm row-spacing for disease development. Among different row directions, peak disease incidence was observed in E-W compared to N-S direction (Fig. 7). Microclimate plays important role in disease development and multiplication. Microclimate of the crop is modified with crop geometry, which may have affected the disease incidence. From this study it is clear that wider row-spacing and E-W row direction can be helpful to decrease the per cent disease incidence.

Grain yield under different crop geometry

HD 2967 produced significantly higher biological and grain yield compared to PBW 550 and PBW 343 (Table 1). Biological yield of PBW 550 was significantly higher than PBW 343 during both the crop seasons. Ram *et al.* (2013) confirmed the findings of this study. The main reason behind higher grain yield in 30 cm row-spacing was low disease incidence. Similarly, Singh *et al.* (1992) reported that wider row-spacing (30 cm) registered higher number of ear heads plant^{-1}, 1000-grain weight and grain yield of wheat compared to closer row-spacing (15 cm).

Table 1. Grain yield and per cent yield losses due to yellow rust incidence under different treatments of Wheat

Treatments	2012-13			2013-14			Mean analysis		
	S*	US**	% yield loss	S	US	% yield loss	S	US	% yield loss
HD 2967	59.61	56.53	5.16	63.39	62.00	2.2	61.50	59.26	3.64
PBW 550	55.23	37.94	31.3	57.95	41.58	28.3	56.59	39.76	29.7
PBW 343	47.83	27.36	42.8	52.34	34.82	33.5	50.08	30.82	38.5
CD (p=0.05)	1.78	1.80	-	1.72	2.59	-	1.62	1.70	-
30.0 cm	50.20	44.01	12.3	54.18	47.89	11.6	52.19	45.94	12.0
22.5 cm	54.76	42.62	22.2	57.27	46.10	19.5	56.02	44.10	21.3
15.0 cm	57.68	35.20	39.0	62.24	44.42	28.6	59.96	39.80	33.6
CD(p=0.05)	2.43	1.65	-	2.24	1.56	-	1.29	0.85	-
N-S	51.68	42.24	18.3	56.14	48.05	14.4	53.58	45.11	15.8
E-W	52.14	43.98	15.7	58.13	50.26	13.5	55.89	44.99	19.5
CD (p=0.05)	2.73	2.29	-	3.89	3.48	-	2.86	3.02	-

*S= Sprayed conditions
**US= unsprayed Conditions

Among different row directions, wheat sown in E-W direction gave higher grain yield than N-S direction during both seasons. But the difference in biological and grain yields were at par with two row directions. This difference might be due to lower rate of yellow rust disease in E-W row direction. Bhan *et al.* (1995) reported that the yield was higher for E-W sown crop (9.63 q ha^{-1}) and lower for N-S sown crop (8.89 q ha^{-1}). Similarly, Pathan *et al.* (2006) concluded that total light interception by crop canopy of wheat and barley crops was higher in E-W than north-south direction when measured at midday at the centre of inter-row space. Grain yields of wheat and barley crops were consistently higher when sown in an E-W than in a N-S direction.

Assessment of yield losses due to yellow rust

Grain yield was drastically reduced under unsprayed conditions. The HD 2967 showed minimum yield loss due to yellow rust. The var. PBW 343 is most susceptible to yellow rust,a nd it showed maximum yield losses in both seasons. Comparison of wheat yield sown under different row-spacings indicated that yield losses due to disease incidence and severity were maximum (39%) in 15 cm row-spacing and were minimum (12.3%) in 30 cm row-spacing. Among row direction, yield losses were higher (18.3%) in N-S compared to E-W direction (14.4%). Yield losses were more during 2012-13 as compared to 2013-14, because of higher yellow rust incidence and severity. Jindal *et al.* (2012) concluded that stripe rust is appearing continuously since 2006-07 in sub-mountainous districts of Punjab and Haryana. The losses in yield due to stripe rust varied between 4.2-68.8% depending on the varietal resistance. Similarly, Khanna *et al.* (2005) concluded that yield loss due to yellow rust can be substantial, ranging from 40% to a complete damage depending upon the growth stage at which the disease incidence occurs. Singh *et al.* (2004) concluded that in Asian continent, leaf and stripe rust could affect production on approximately 60 million ha (63%) and 43 million ha (46%), respectively, if susceptible cultivars are grown. Similarly, Gashaw and Baize (2014) also estimated that yield losses due to yellow, leaf and stem rust were ranging from 15-20, 10-15 and 10%, respectively.

Relationship between yellow rust and grain yield

Relationship between yellow rust incidence and grain yield showed that grain yield was negatively associated with yellow rust severity. Highly significant relationships were observed with R^2 value 0.85 under different row-spacing.

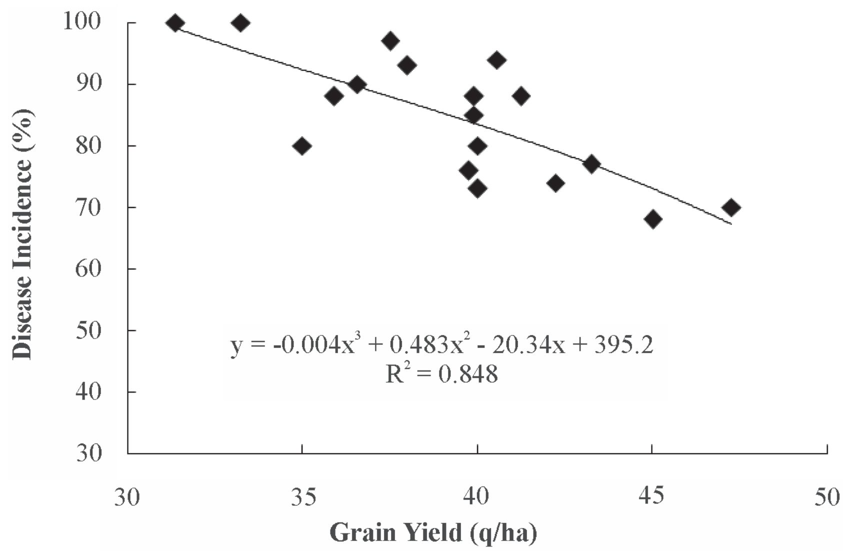

Fig. 8. Relationship between yellow rust and grain yield under different row spacing in wheat

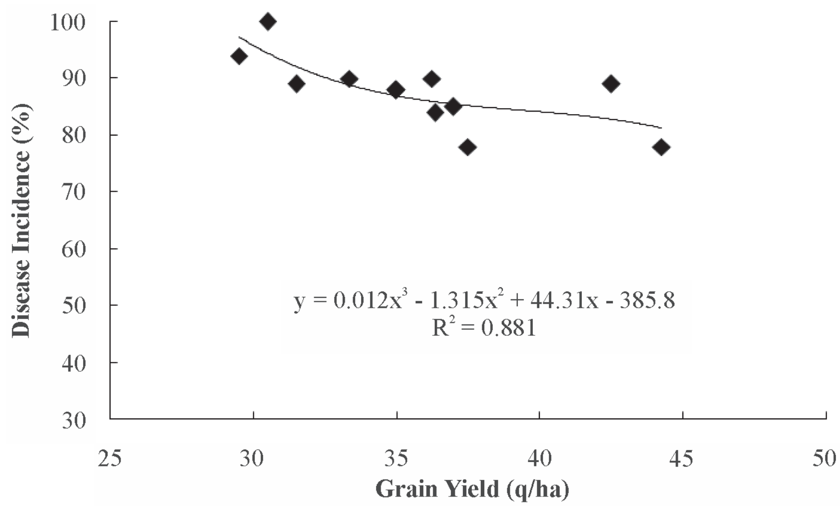

Fig. 9. Relationship between yellow rust and grain yield under different row direction in wheat

This indicates that 85% variability in grain yield was due to yellow rust (Fig. 8) whereas among two row-directions the R^2 value of 0.88 was observed (Fig. 9). Negative correlation coefficients were observed between grain yield and yellow rust incidence. In corroboration with this study, Afzal *et al.* (2007) also reported that there exists a direct linkage between the disease level and the yield loss in the most common commercially adopted wheat varieties. The yield was negatively correlated with the proportion of leaf area affected by stripe rust. The correlation coefficient (-0.68) depicted a highly significant effect of stripe rust on wheat yield.

Conclusion

It can be concluded from present study that yellow rust of wheat is significantly influenced by weather parameters. The crop sown under wider row spacing and in E-W direction gave higher grain yield due to lesser disease incidence.

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