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Short Communication

Genetics of *Fusarium* head blight resistance in three wheat genotypes

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Abstract

Fusarium head blight (FHB) is a global concern as recent outbreaks reported in Canada, Europe, Asia, Australia and South America. The disease has emerged as one of the most important plant diseases worldwide in 21st century. One of the major threats posed by FHB fungus is the mycotoxin production which is harmful to human and animal health. Development of disease resistant cultivars is the only effective method for managing the disease. Control of these pathogen / *Fusarium* spp. is also challenging due to limited sources of known resistance. The famous Chinese wheat cultivar Sumai 3 and Frontana are the main sources of resistance to this disease. For genetic analysis and incorporation of FHB resistance into recently released high yielding wheat cultivars, HD 2967 and DPW 621-50, crosses were made with Sumai 3, Frontana and Aldan. The F_2 plants from the crosses HD 2967/Frontana (140), HD 2967/Aldan (150), HD 2967/Sumai 3 (169) and DPW 621-50/Sumai 3 (182) were screened for resistance under controlled conditions. Disease score was recorded to identify resistant, moderately resistant and susceptible plants. The genetic ratios for resistance to FHB indicated a complex nature of resistance in all the three donors.

Key words: Fusarium head blight, wheat, genetics, Aldan, Sumai 3, Frontana, HD2967, DPW 621-50

Fusarium head blight (FHB), caused by *Fusarium spp.* is one of the most destructive diseases of wheat (*Triticum aestivum* L.). FHB causes about 10-70% yield loss during epidemic years (Matthies and Buchenauer 2000). Other than yield losses, FHB can also reduce the quality of wheat grains as it is associated with trichothecene mycotoxins, which are detrimental to the human health (Li et al. 2010). Currently, FHB is one of the minor wheat diseases in India but if rain occurs during mid-anthesis stage in the Northern India, the fungus can cause yield losses. *F. graminearum* causing scab of wheat was first reported from Arunachal Pradesh in north east (Roy 1974) and from Wellington, Nilgiri Hills, Tamil Nadu in South (Brahma and Singh 1985). Severe head scab appeared on durum cultivar PDW 274 in the Gurdaspur area of Punjab during 2005 as continuous rain occurred during heading (Saharan et al. 2007). Control of the pathogen has been difficult, because of the complex nature of the host/pathogen/environment interaction. Most of the wheat cultivars are susceptible or moderately susceptible to FHB and no cultivar with immune response to this disease has been identified (Rudd et al. 2001; Lin et al. 2004). Sumai 3 is the most successful and widely used resistant germplasm in breeding programs (Buerstmary et al. 2009). The quantitative control of FHB resistance makes it difficult to determine resistance mechanisms and breed resistant cultivars. Incorporation of resistance from the donor parent becomes cumbersome as accumulating a greater number of QTLs requires specific breeding approach. As an approach, Sumai 3, Frontana and Aldan were used as donor parents for crossing with commercially grown agronomically superior Indian wheat cultivar HD 2967 and DPW 621-50. The F_2 populations from four crosses which had enough population size were used to study the genetics of FHB resistance and identify plants with high levels of resistance to this disease.

In present study two high yielding wheat varieties HD 2967 and DPW 621-50 were used as recipients whereas Aldan, Sumai 3 and Frontana were used as

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the donors of Fusarium head blight resistance. Four cross combinations (HD 2967/Frontana; HD 2967/ Aldan; HD 2967/Sumai 3; DPW 621-50/Sumai 3) were attempted successfully during 2014-15 crop season at experimental field block of IIWBR, Karnal. The crossed seed from these lines were raised at IIWBR-RS, Dalang Maidan (HP) as F_1 population during 2015. Selfed seed from these crosses were used to raise F_2 populations at Karnal during crop season 2015-16. The experiment was conducted under controlled conditions maintained in polyhouse. Five spikes at mid anthesis from each F_2 plant of all the four populations were inoculated with *Fusarium graminearum* isolates by placing a tiny tuft of cotton soaked with the inoculum in a floret of the middle spikelet. Each spike was covered with a plastic bag to prevent cross contamination and desired level of humidity (RH> 90%) was maintained for 72 hours by providing misting. Head blight data was recorded visually by counting healthy and infected spikes as well as spikelets per spike in each plant after seven days of inoculation. Per cent infected spikelet (% disease severity) was calculated as: (No. of infected spikelet/Total spikelet per spike) *100. The per cent disease score was converted into a scale of 0-5 as suggested by Wilcoxson et al. 1992. Chi-square test was employed to test the goodness of fit for calculating the probabilities and estimates of gene(s) number.

The range and mean of FHB infection is given in Table 1. The disease severity as indicated by per cent spikelet infection was high in the populations, HD 2967/ Frontana (36.02), HD 2967/Aldan (45.05), HD 2967/ Sumai 3 (46.93) and DPW 621-50/Sumai 3 (81.30, 49.20). Minimum spikelet infection was 10.37 per cent in HD 2967/Frontana and 11.11 per cent in other three populations HD 2967/Aldan, HD 2967/Sumai 3 and DPW 621-50/Sumai 3. The donors, Frontana, Aldan and Sumai 3 were observed resistant with a disease severity of 8.65, 12.37 and 6.47 per cent, respectively. Based on per cent spikelet infection, FHB severity was categorized in to six different classes based 0-5 scale. Number of F_2 plants in each class for all the four populations is given in Table 2. The genetic ratios for resistance to FHB indicated a complex nature of resistance in all the three donors used in the four populations. The absence of any plant with a disease severity response of less than 10 per cent (Table 2) indicated absence of dominant gene reaction in all the four combinations studied. Complete or very high degree of susceptibility was recorded in very few plants. The frequency distribution of FHB disease response in all the four populations was continuous in nature and comparable to the maximum level of severity as evidenced from the parents. In present study, we tried to group the disease responses in to two categories of resistant-moderately resistant (R-MR) and susceptible (S) plants. The disease response of upto 50 per cent was categorized as resistant-moderately resistant (R-MR) and the plants with a more than 50 per cent severity were classified as susceptible (S). The chi square analysis carried out for the fitness of good indicated that the resistance to FHB in the three donors used in the study was governed by 3-4 genes having minor additive genes (Table 3). In the populations HD 2967/Frontana and HD 2967/Aldan, resistance incorporated from Frontana and Aldan was

Table 1. Range and mean of the infection response to *Fusarium* head blight observed in the four F_2 populations

Parents/Cross	% Av. spikelet infection		
	Min.	Max.	Av.
HD 2967/Frontana	10.37	100.00	36.02
HD 2967/Aldan	11.11	100.00	45.05
HD 2967/Sumai 3	11.11	100.00	46.93
DPW 621-50/Sumai 3	11.11	100.00	49.20
Frontana	-	-	8.65
Aldan	-	-	12.37
Sumai 3	-	-	6.47
HD 2967	-	-	44.79
DPW 621-50	-	-	56.78

Table 2. Number of plants based on disease scale to Fusarium head blight in F_2 populations

Disease scale	No. of plants in F_2 populations			
	HD 2967/ frontana	HD 2967/ Aldan	HD 2967/ Sumai 3	DPW 621 -50/Sumai 3
0	0	0	0	0
1	0	0	0	0
2	38	12	27	32
3	85	96	88	87
4	9	34	28	40
5	8	8	26	23
	140	150	169	182

Table 3. Chi square analysis for fitness of good at 5% level of significance in all the four F_2 populations studied

Cross	No. of F_2 plants		Chi square and *P* value		
	R–MR	S	2 genes	3 genes	4 genes
HD 2967/Frontana	132	8	5.894 (0.015)	0.069 (0.793)	3.100 (0.078)
HD 2967/Aldan	142	8	7.044 (0.008)	0.215 (0.643)	2.416 (0.120)
HD 2967/Sumai 3	143	26	1.286 (0.257)	24.067 (<0.001)	83.903 (<0.001)
DPW 621-50/Sumai 3	159	23	0.003 (0.955)	12.673 (<0.001)	54.398 (<0.001)

R-MR = resistant – moderately resistant; S = susceptible

governed by three genes. The inheritance of resistance to FHB are reported in previous studies describing an additive-dominance model (Snijders 1990; Lin et al. 1992). Either two or three genes were considered to contribute to resistance in the Brazilian cultivar Frontana (Van Ginkel et al. 1996). However, some researchers have speculated polygenic control of FHB resistance in Frontana (Gocho et al. 1992).

Differential response was observed in the other two crosses HD 2967/Sumai 3 and DPW 621-50/Sumai 3 which had same donor. In the cross HD 2967/Sumai 3, chi square analysis for fitness of good test indicated that the phenotypic ratios did not fit in to 2, 3 or 4 gene models. Whereas, in the cross DPW 621-50/ Sumai 3, the genetic analysis revealed that the resistance in Sumai 3 was governed by two genes. In a study by Ban and Suenaga (2000) it was observed that the FHB resistance of Sumai 3 was controlled by two major genes with additive effects using DHLs. These findings were supported by previous studies on Sumai 3 (Yang 1994; Van Ginkel et al. 1996). The resistant plants identified in present study are being advanced for further use in wheat breeding program.

Authors' contribution

Conceptualization of research (MSS, SK); Designing of the experiments (MSS, SK); Contribution of experimental materials (SK, MSS); Execution of field/ lab experiments and data collection (SK, MSS, VP); Analysis of data and interpretation (SK, MSS, RC, GPS); Preparation of manuscript (SK, MSS, GPS, RC).

Declaration

The authors declare no conflict of interest.

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