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IMPACT OF RESISTANCE IN DIMINUTION OF INFECTION AND QUANTITATIVE LOSSES CAUSED BY KARNAL BUNT (*NEOVOSSIA INDICA*) IN BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

Reaction of *Neovossia indica* in bread wheat, with particular reference to the role of resistance in minimizing its infection and quantitative loss caused by it, were observed with virulent isolate of *Neovossia indica* in a set of population. Whole set of population consisted of resistant parents (HD 29, Lok 1 and Raj 3777), susceptible parents (WL 711, UP 262 and UP 2425), F_1, F_2 and backcross (BC_1 and BC_2) generations. F_1 was derived from crossing between resistant and susceptible parents in half diallel fashion. Maximum percent infection i.e., 17.9% was recorded in the susceptible parent *i.e*, WL 711, which resulted in 4.65 % (maximum) grain yield loss, while only 0.86 % (minimum) infection resulted in 0.22% grain yield loss was recorded in the back cross generation of the cross Raj 3777/ Lok-1 (resistant x resistant). However, overall 6.0 % percent infection and grain yield loss 1.49% was recorded by all generations. The present study reveals good scope for resistance breeding in minimizing the percent infection and ultimately yield loss due to infection of Karnal bunt.

INTRODUCTION

Wheat is one of the most important and widely cultivated staple food crops among the cereals and is contributing about 30% to the food basket of the country. To feed the growing population, the country's wheat requirement by 2030 has been estimated at 100 million metric tons. To achieve this target, the wheat production has to be increased at the rate of < 1mmt per annum (Sharma *et al.*, 2012). However, wheat crop production is constrained by a number of diseases (Goel *et al.*, 2005). Among these diseases, Karnal bunt is a serious floral infecting disease of wheat, caused by Neovossia indica (Mitra) Mundkar (Syn. Tilletia indica). It was first reported at Karnal (Haryana) by Mitra (1931). It continued to be a minor disease till 1968, however, in 70s and 80s, it emerged as an important disease of wheat (*Triticum aestivum* L.). It has been distributed in major wheat growing area of Southern Nepal, Pakistan, Lebanon, Sweden, Syria, Turkey, Afghanistan, Iran, Mexico and USA (Ykema *et al.*, 1996; Crous *et al.*, 2001 and Haq *et al.*, 2002). In India, Karnal bunt occurs in the states of Punjab, Haryana, Uttaranchal, Jammu and Kashmir, Himachal Pradesh, Delhi, Rajasthan and Bihar and it is known by various names such as kernel smut, karnal bunt and partial bunt etc. (Nagarajan *et al.*, 1997).

The pathogen is known to infect bread wheat, durum wheat and triticale (Agarwal *et al.*, 1977). Karnal bunt is a disease which not only causes the reduction of yield but also deteriorates the quality of grains and its products and affects the market value of wheat. The fungus does not produce any toxic compounds in leaf, stem tissue, or seed that pose health risks when consumed. However, fungus affects flour quality if more than 3 percent of the grains are bunted because it produces tri-methylamine, which gives off a fishy odor. The Karnal bunt pathogen causes infection on floral parts, infected grains portions of kernel are replaced with the mass of teliospores of the fungus and leads to reduction in grain weight, vigour and germinability of the seeds (Aujla *et al.*, 1985; Bansal *et al.*, 1984; Bedi and Meeta, 1981; Bedi *et al.*, 1981 and Warham, 1990).

Karnal bunt has become a potential threat to international trade of commercial grain and wheat germplasm, as importing countries insist on zero tolerance level for fear of introducing the disease. International quarantine policies against the disease may restrict the free flow of the global wheat trade (Royer and Rytter, 1988). Chemical control of the disease with fungicides is only partially effective owing to the varied modes of spore transmission. It is commercially impractical because of zero Karnal bunt tolerance level for Karnal bunt spores imposed by importing countries. At this juncture, development of resistant varieties is the only economic and sustainable disease management strategy for Karnal bunt pathogen. Keeping in view the importance of Karnal bunt resistance, the present investigation was carried out to gather information on Karnal bunt (KB) infection and yield loss with special reference to available resistance/ susceptible genes present in genetic material studied.

MATERIALS AND METHODS

The material comprised of six bread wheat (*Triticum aestivum*) genotypes. Three of which, HD 29, Lok 1 and Raj 3777 have been resistant and WL 711, UP 2425 and UP 262 which were susceptible to Karnal bunt (*Neovossia indica*). The parentage of lines used in the experiment is as under:

HD 29: (HD 2160-HD 1977) / (HD 7449-HD 1944) / HD 2136;

Lok 1: S 308 / S 331;

Raj 3777: Raj 3160 / HD 2449;

UP 2425: HD 2320 / UP 2263;

UP 262: S 308 / Bajio 66;

WL 711: (S 308 / Chris) // Kalyan Sona

These six genotypes were crossed in half diallel fashion to get the F_{1s} (first filial generation), namely 'WL 711' x 'HD 29' (susceptible x resistant), 'WL 711' x 'Lok 1'(susceptible x resistant), 'WL 711' x 'Raj 3777'(susceptible x resistant), 'WL 711' x 'UP 262' (susceptible x susceptible), 'WL 711' x 'UP 2425' (susceptible x susceptible), 'UP 262' x 'HD 29' (susceptible x resistant), 'UP 262' / 'Lok 1'(susceptible x resistant), 'UP 262' x 'Raj 3777' (susceptible x resistant), 'UP 262' x 'UP 2425' (susceptible x susceptible), 'HD 29' x 'Lok 1' (resistant x resistant), 'Raj 3777' x 'Lok 1'(resistant x resistant), 'Raj 3777' x 'HD 29' (resistant x resistant), 'UP 2425' x 'HD 29' (susceptible x resistant), 'UP 2425' x 'Lok 1' (susceptible x resistant), 'UP 2425' x 'Raj 3777' and then these F_{1s} seeds were raised to advance the material to F_2 (second filial) and back cross (BC_1 and BC_2) generations. To have enough F_1 seed for trial, fresh crosses between the parents were also attempted.

Thus, the complete set of experimental material composed of 6 generations, *i.e.*, P_1, P_2, F_1, F_2, BC_1 and BC_2 was screened in randomized block design (RBD) with inter and intra row spacing of 23 cm. and 10 cm., respectively with three replications under artificial epiphytotic and optimal agronomic conditions at the Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, India. The plot size for each of the six parents was paired row, while 4 rows, 10 rows and 6 rows were assigned to each F_1 hybrids, F_2 and BC_1 and BC_2 generations, respectively by keeping fixed row length of 1 meter. The recommended agronomic practices were followed to obtain a good crop.

At physiological growth stage 49 (Zadok *et al.*, 1974), 2 mL of sporidial suspension (103-104 sporidia per ml) of teliospores of mix culture of virulent isolates of Karnal bunt, received from Directorate of Wheat Research (DWR), Karnal was inoculated into the boot of the all spikes of individual plant, using a hypodermic syringe (Aujla *et al.*, 1980) during evening hours (4-6 PM). To provide favorable conditions for successful infection and disease development, high relative humidity (90 per cent) was maintained in the field by spraying plants with an overhead mist sprayer for at least 6 hours in a day (Aujla *et al.*, 1982). The intensity of karnal bunt infection on individual lines was recorded according to the scale of Aujla *et al.* (1989), taking severity (total bunted grains in a spike) and response (extent of bunt infection on individual grains) into consideration at maturity. Response was categorized into five grades of infection depending on the intensity of bunt infection in individual grain. Grains from each spike were scored for disease intensity and percent coefficient of infection was calculated following Aujla *et al.* (1989). The grain yield loss per plot was determined using the following formula (Singh, 1986):

$$\text{Grain yield loss per plot} = \frac{\text{actual yield/plot} \times \text{\%kernal bunt infected grains} \times 0.256}{100}$$

RESULTS

Percent of infection due to *Neovossia indica* ranged from 0.86 % in BC_1 (back cross) population of the cross Raj 3777/ Lok 1 (resistant/resistant cross) to 17.9 % in a susceptible parent (WL 711) from the material studied. In the same way, yield loss ranged from 0.22 per cent (in BC_1 of resistant/resistant cross *i.e.*, Raj 3777/Lok 1) to 4.65 per cent (in WL 711, a susceptible parent) (Table 1).

The average percent of infection and grain yield loss of 5.96 and 1.49 percent, respectively was recorded in different generations. The lowest average generation wise percent infection and yield loss of 3.93 and 0.86 %, respectively was estimated in F_{1s}, due to maximum resistant reaction against the Karnal bunt from its population, while, the highest averaged grain yield loss of 1.86% by parents, in which susceptible genotypes expressed severe infection (9.6% in UP 2425 to 17.9% in WL 711). The highest averaged percent infection (7.26%) was recorded in BC_1 generation, where out of fifteen different populations; thirteen were derived from backcrossing F_1 with susceptible genotypes. The minimum grain yield loss and percent of infection in backcross population of resistant x resistant cross and the maximum grain yield loss in susceptible variety indicates the usefulness of resistance mechanism for minimum percent infection and ultimately maximum yield gain.

Among susceptible parents (WL 711, UP 262 and UP 2425), the per cent Karnal bunt infection and percent yield loss ranged from 9.6 to 17.9 and 2.50 to 4.65, respectively whereas it was negligible (0.90 to 1.02 and 0.23 to 0.26, respectively) in case of the resistant parents (HD 29, Lok 1 and Raj 3777). The same pattern of percent KB infection and grain yield loss indicating the contribution of resistant genes in minimizing the percent infection and ultimately yield loss was observed in different generations such as hybrid (F_{1s}) and segregating generations (F_{2S}, BC_{1S} and BC_{2S}).

In F1 crosses, percent of infection and yield loss (%) was estimated to be 3.93 and 0.86, respectively. All F_{1s} were resistant excluding two susceptible x susceptible F_1 cross. The cross Raj 3777/ Lok 1 (resistant x resistant) had the minimum percent infection (1.26) and yield loss (0.32%), while its parents i.e., Raj 3777 and Lok 1 exhibited 0.90% and 1.02% infection,

Table 1: Estimates of percent yield losses in different generations of bread wheat crosses, due to *Neovossia indica* infection

Generations	Per cent infection	Grain yield plot[1] (0.5 m²)	Per cent yield loss
Parents			
HD 29	0.96	427.41	0.25
Lok 1	1.02	394.25	0.26
Raj 3777	0.90	346.16	0.23
WL 711	17.9	375.84	4.65
UP 262	12.6	435.41	3.28
UP 2425	9.6	496.66	2.50
Mean	7.16	412.62	1.86
F_{1s}			
WL 711 / HD 29	3.86	454.91	0.98
WL 711 / Lok 1	4.48	300.59	1.15
WL 711 / Raj 3777	4.39	645.59	1.12
WL 711 / UP 262	6.12	307.25	1.57
WL 711 / UP 2425	3.70	385.91	0.95
UP 262 / HD 29	4.76	394.64	1.23
UP 262 / Lok 1	4.03	288.84	1.03
UP 262 / Raj 3777	4.82	343.16	1.23
UP 262 / UP 2425	6.39	412.75	1.64
HD 29 / Lok 1	1.38	331.00	0.35
Raj 3777 / Lok 1	1.26	348.25	0.32
Raj 3777 / HD 29	2.02	361.66	0.52
UP 2425 / HD 29	3.80	473.91	0.97
UP 2425 / Lok 1	4.09	443.34	1.05
UP 2425 / Raj 3777	3.83	459.59	0.98
Mean	3.93	396.76	0.86
F_{2s}			
WL 711 / HD 29	8.50	418.63	2.18
WL 711 / Lok 1	8.79	492.25	2.25
WL 711 / Raj 3777	8.00	390.16	2.05
WL 711 / UP 262	9.01	398.13	2.31
WL 711 / UP 2425	6.90	457.75	1.77
UP 262 / HD 29	8.80	403.84	2.25
UP 262 / Lok 1	8.87	490.25	2.27
UP 262 / Raj 3777	8.71	464.66	2.23
UP 262 / UP 2425	8.96	393.59	2.30
HD 29 / Lok 1	2.65	299.50	0.68
Raj 3777 / Lok 1	2.77	417.00	0.71
Raj 3777 / HD 29	2.37	704.25	0.61
UP 2425 / HD 29	7.01	472.25	1.79
UP 2425 / Lok 1	7.33	455.16	1.88
UP2425 / Raj 3777	6.97	373.84	1.78
Mean	7.04	442.08	1.80

respectively indicating that the F_1 of these parents showed superior performance over better parents (Raj 3777). The results revealed that there was scope for isolating Karnal bunt resistant transgressive segregants / genotypes with minimum/ zero level of infection. The highest KB infection and yield loss of 6.39 and 1.64%, respectively was observed from UP 262/ UP 2425, a susceptible x susceptible cross. Therefore, the hybrid between susceptible parents should be discouraged. If we consider the resistant and susceptible genes, the highest percent of infection and yield loss (%) ranged from 3.70 to 6.39 and 0.95 to 1.64, respectively in the cross combinations involving one or more susceptible parents, while it was 1.26 to 2.02 and 0.32 to 0.52, respectively in resistant x resistant crosses.

Among the F_{2s}, an overall percent of infection of 7.04 and yield loss of 1.80 per cent was recorded. The highest KB infection (9.01%) and decrease in yield (2.31%) was estimated in the susceptible x susceptible cross, WL 711/ UP 262, while lowest were in resistant x resistant cross, Raj 3777/ HD 29 (2.37% and 0.61%, respectively). Perusal of results obtained from back cross generations revealed that the average KB infection and yield decrease in BC_{1s} was 7.26% and 1.81%, respectively whereas in BC_{2s}, it was 4.40 and 1.12 %, respectively. However, highest yield loss (3.01 and 2.25 %) was estimated in BC_1 and BC_2 generations, respectively of the cross WL 711/ UP 262, while lowest decrease in yield was recorded in BC_1 and BC_2 generation of the cross Raj 3777/ Lok 1 (0.22 and 0.74%, respectively). The same situation was recorded for percent of infection. In BC_1 and BC_2 generations, highest percent infection (11.78 and 8.77, respectively) was estimated in cross WL 711/ UP 262, while lowest percent infection was recorded in cross Raj 3777/ Lok 1 (0.86 and 2.89%, respectively).

DISCUSSION

Specially generated genetical populations have been used by several investigators to investigate and demonstrate inheritance of traits in different crop plants (Swati and Goel, 2010 and Goel *et al.* 2010). Results from the present investigation revealed that the resistance plays a major role in minimizing the loss due to Karnal bunt. It is confirmed by the differences in the

Table 1: Cont..........................

Generations	Per cent infection	Grain yield plot[1] (0.5 m²)	Per cent yield loss
$BC_{1's}$			
(WL 711 / HD 29) / WL 711	9.40	418.84	2.31
(WL 711 / Lok 1) / WL 711	9.89	341.25	2.53
(WL 711 / Raj 3777) / WL 711	8.97	296.59	2.19
(WL 711 / UP 262) / WL 711	11.78	359.09	3.01
(WL 711 / UP 2425) / WL 711	10.17	545.16	2.50
(UP 262 / HD 29) / UP 262	9.06	449.84	2.22
(UP 262 / Lok 1) / UP 262	9.78	415.85	2.50
(UP 262 / Raj 3777) / UP 262	9.27	307.66	2.27
(UP 262 / UP 2425) / UP 262	10.3	401.16	2.64
(HD 29 / Lok 1) / HD 29	1.30	498.50	0.33
(Raj 3777 / Lok 1) / Raj 3777	0.86	333.09	0.22
(Raj 3777 / HD 29) / Raj 3777	1.70	420.34	0.40
(UP 2425 / HD 29) / UP 2425	7.88	446.34	2.01
(UP 2425 / Lok 1) / UP 2425	8.70	412.41	2.13
(UP 2425 / Raj 3777) / UP 2425	7.79	369.75	1.60
Mean	7.26	401.06	1.81
$BC_{2's}$			
(WL 711 / HD 29) / HD 29	3.46	417.66	0.89
(WL 711 / Lok 1) / Lok 1	3.88	3.7300	1.00
(WL 711 / Raj 3777) / Raj 3777	3.70	369.25	0.94
(WL 711 / UP 262) / UP 262	8.77	591.85	2.25
(WL 711 / UP2425) / UP 2425	7.20	368.85	1.80
(UP 262 / HD 29) / HD 29	4.30	419.75	1.10
(UP 262 / Lok 1) / Lok 1	4.71	459.59	1.20
(UP 262 / Raj 3777) / Raj 3777	3.95	520.09	1.01
(UP 262 / UP 2425) / UP 2425	7.77	485.09	1.98
(HD 29 / Lok 1) / Lok 1	3.00	321.85	0.77
(Raj 3777 / Lok 1) / Lok 1	2.89	344.12	0.74
(Raj 3777 / HD 29) / HD 29	3.60	473.91	0.92
(UP 2425 / HD 29) / HD 29	2.90	400.66	0.74
(UP 2425 / Lok 1) / Lok 1	3.05	523.75	0.78
(UP 2425 / Raj 3777) / Raj 3777	2.86	509.91	0.73
Mean	4.40	438. 62	1.12

yield levels between different genotypes and generations depending on the involvement/ absence of the resistance source in the pedigree of independent cross.

The earlier findings too suggest that to avoid heavy yield losses due to the pathogen, resistance is the only sustainable disease management strategy for minimizing the karnal bunt infection (Chauhan and Singh, 1997). Fuentes-Davila and Rajaram (1994) reported the mean percentage infection (ranged from 0.19 to 2.95 %) in resistant American, Chinese and Indian wheat lines while the maximum even up to 63.5 % was recorded in susceptible checks. They also postulated that the availability of resistant cultivars would reduce the risk of introduction of Karnal bunt to other wheat production areas, as resistant lines could provide excellent management of the disease.

Similarly, Singh *et al.* (2003) and Goel *et al.* (2006) stated the importance of resistance in minimizing the infection rate and ultimately lead to wheat disease management. Duveiller *et al.* (2007) reported that genetic resistance is the main method for controlling obligate parasites. Goel *et al.* (2007) also stated the negative correlation between the disease severity and grain yield. Similarly, Jat *et al.* (2013) reported that loss was lowest (4.55%) in case of release of 1 pair of adult of beetle (lower infestation), and highest (44.57%) in case of release of 16 pair of bettle adult (higher infestation). It could therefore be concluded from the study that the use of suitable Karnal bunt resistant cultivars would be the unsurpassed option in the management of this disease. Additionally, it is recommended that a breeding programme should be established for the introgression of Karnal bunt resistance in the susceptible popular cultivars to maintain the popular wheat cultivars for reduction in yield losses and eventually the quality of wheat grains.

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