

## Identification of new resistant sources in bread wheat against Karnal bunt incited by *Tilletia indica*

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Wheat is an extensively grown cereal crop. Sporadic fungus, *Tilletia indica*, a causal agent of Karnal bunt, hinders wheat export as it has a zero-tolerance limit. The use of a resistant cultivar is the most practical and promising control measure for managing the KB. Keeping in view, two-hundred and thirty-eight bread wheat genotypes were screened against Karnal bunt of wheat under artificial inoculation conditions during the 2022-23 and 2023-24 *rabi* seasons at ICAR-Indian Agricultural Research Institute, New Delhi. The significant variability of disease incidence was assessed among all the genotypes. In the year 2022-23, the COI ranged from 0.45 to 74.43% and fifty-three genotypes were found resistant, 49 genotypes were moderately susceptible, 44 genotypes were susceptible, and 58 were highly susceptible. During the 2023-24, moderate to high incidence of Karnal bunt was assessed. During this year, COI ranged from 0.42 to 37.23% and 26 genotypes were found resistant, 86 genotypes were moderately susceptible, 60 genotypes were susceptible and 45 were highly susceptible. Comparative analysis of two-year data revealed that 17 genotypes *viz.* IC111822, CHK1, IC296437, IC311079, IC35076, IC416046, IC416111, IC47797, IC531275, IC531820, IC529681, IC532086, IC566636, IC582705, IC398298, IC273946 and EC362041 showed the stable resistance to Karnal bunt of wheat. Further, these genotypes can be used for the development of KB-resistant varieties.

**Keywords :** Coefficient infection, genotypes, Karnal bunt, *Tilletia indica*, wheat

### INTRODUCTION

Wheat is an important staple food crop that has been cultivated for thousands of years. Major species grown worldwide are *Triticum aestivum*, a hexaploid species called “common” or “bread wheat” and *T. durum*, a tetraploid species called pasta wheat (Yadav, 2023). Wheat grains have good nutritive value and are one of the main protein sources in middle-income and least-developed countries (Ramadaset al. 2020). India is the second largest producer of wheat after China. The country has the potential to become a larger wheat exporter in the modern era of globalization and liberalization since it has an excess supply of wheat and the ability to produce more. Due to its high gluten content and

golden-brown hue, Indian wheat grains are being imported by Middle Eastern and South Asian nations, making Indian wheat more competitive in the global market (Thirumalaisamy et al. 2006). However, under the Sanitary and Phytosanitary Agreement, wheat exporters experienced trade hurdles, such as restricted transit of consignment to other countries, due to the prevalence of the KB disease. *Tilletia indica* (syn. *Neovossia indica*), which causes Karnal bunt or partial bunt of wheat, was initially identified by Mitra from Karnal, India (Mitra, 1931). According to Jones (2007), this disease has also been reported in Pakistan, Nepal, Afghanistan, Iran, South Africa, Mexico, and a few restricted places in the southwestern United States. The pathogen is a soil, seed and air-borne fungus that produces teliospores, which is the main source of inoculum that can resist adverse environments and live for several years in the soil (Manakkatt et

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*al.* 2024). The germinated teliospores produce sporidia, infects rachis, glume, lemma, and correct only dikaryotic mycelium by anastomosis. The pathogen enters through the germinal end of grains and develops within the pericarp, converting kernels into sori-filled with black teliospores. Infected grains emit a foul smell due to the compound triethylamine and the grains become unfit for consumption. Management of the disease through cultural practices and chemical treatment has been unsuccessful. The only alternative to avoid this disease is to develop cultivars resistant to KB (Kumar *et al.* 2014). *T. indica* shows a high level of variability, which is attributed by the presence of heterokaryosis with bipolar mating type (Gurjar *et al.* 2019; Singh *et al.* 2020) and makes the resistance breeding programs challenging. For effective breeding programs of KB resistance, efficient screening under epiphytic conditions, an understanding of the pathogen variability, host's or related species resistance source sources, and host range are necessary. The accuracy of genetic analysis of resistance increased after the use of a heterogenous mixture of inoculum for Karnal bunt screening (Sirari *et al.* 2008). The stability of resistance is still unresolved as there is a complex interaction between host and pathogen (Gurjar *et al.* 2019). Because of these difficulties, very limited Karnal bunt resistance genotypes are available in the primary gene pool of wheat (Bishnoi *et al.* 2020). Keeping in view, the present investigation was aimed to screen the wheat genotypes against Karnal bunt of wheat under net-house conditions, which can be used in developing resistance cultivars to alleviate losses in the farmer's field.

## MATERIALS AND METHODS

The disease screening of wheat genotypes was carried out during 2022-23 and 2023-2024 at the Division of Plant Pathology, ICAR-Indian Agricultural Research Institute, New Delhi under net house conditions.

### **Sowing and inoculation of wheat genotypes**

Two hundred and thirty-eight genotypes of bread wheat were procured from ICAR-National Bureau of Plant Genetic Resources, New Delhi. These

genotypes were sown in the net house during the 2022-23 and 2023-24 *rabi* season. Inoculation was completed in January to March as the tillers came to the boot leaf stage. At the boot leaf stage, Z-49 stage (Zadok *et al.* 1947) of the wheat, fresh pathogen spore inoculum was prepared by adding water into the different isolates of *T. indica* culture tubes and then scrapped with the help of a needle. The spore suspension was mixed and then filtered with a double-layer muslin cloth to remove the media. The spore concentration was measured with a haemocytometer and maintained at 10,000 sporidia /ml. Five ear-heads of each genotype were inoculated by injecting 1 ml ( $10^4$  sporidia / ml) inoculums in a hypodermic syringe during the evening hours (Aujla *et al.* 1987). High relative humidity (> 80%) was maintained under the net house for two weeks after inoculation of the pathogen (Kumar *et al.* 2014).

### **Grading and calculating the coefficient of infection(COI)**

At maturity of wheat, inoculated ear-heads were harvested, threshed and infected grains were graded into five categories (Fig.1) viz. Healthy seed of wheat, I-Seed with germinal tip infection, II-infection advancing to the kernel groove (1/2th grain), III- 3/4th of the seed infected and IV-"Canoe" symptoms hollowing out of seed interior based on the endosperm area converted into *T. indica* teliospores. The percentage of incidence was recorded and the coefficient of infection (COI) was calculated as per the method given by Aujla *et al.* (1989).

$$\% \text{ COI} = \frac{\sum X_i Y_i}{N} \times 100$$

Where,  $X_i$  and  $Y_i$  are numerical ratings and the number of grains in the  $i^{\text{th}}$  category, respectively and  $i$  ranges from 0 to IV (grade of infection).

Coefficient of infection (COI) = [(0.25 × no. seeds in infection category 0.25) + (0.5 × no. of seeds in infection category 0.5) + (0.75 × no. seeds in the infection category 0.75) + (1.0 × no. seeds in infection category 1.00)] × 100/ total grains.

**Table 1** :Screening bread wheat germplasm against Karnal bunt of wheat under net house conditions (2022-23)

Sl. No.	Accession number	% KB incidence	*COI	Disease response	Sl. No.	Accession number	% KB Incidence	*COI	Disease response
1	IC111687	29.80	12.24	S	121	IC384528	30.30	12.12	S
2	IC111738	19.71	8.41	MS	122	IC384555	13.33	6.07	MS
3	IC111822	9.09	2.46	R	123	IC532086	4.29	1.85	R
4	IC111914	15.57	6.35	MS	124	IC532238	14.58	8.33	MS
5	CHK1	1.63	0.61	R	125	IC5322489	0	0	-
6	IC128211	32.98	13.91	S	126	IC532262	35.58	19.47	S
7	IC128388	4.31	1.72	R	127	IC532149	2.63	0.65	R
8	IC138384	25.60	9.75	MS	128	IC532099	15.18	6.32	MS
9	IC138419	71.75	42.74	HS	129	IC532414	40.97	16.84	S
10	IC138426	23.80	10.71	S	130	IC079009	12.63	7.89	MS
11	IC252487	15.72	5.18	MS	131	IC262866	18.34	7.79	MS
12	IC252660	49.01	23.28	HS	132	IC279876	0	0	-
13	IC252824	47.01	18.54	S	133	IC361690	14.67	8.42	MS
14	IC252844	13.79	6.28	MS	134	IC381179	7.59	4.27	R
15	IC252853	6.50	3.25	R	135	IC078988	4.38	2.41	R
16	IC252876	18.03	6.83	MS	136	IC082221	24.28	10.17	S
17	IC252928	6.25	1.56	R	137	IC082225	33.57	14.41	S
18	IC296437	5.47	2.05	R	138	IC423446	5.95	2.38	R
19	IC296530	7.14	4.46	R	139	IC082279	30.50	17.79	S
20	IC296538	75.00	26.56	HS	140	IC082302	13.88	6.42	MS
21	IC296743	2.10	1.31	R	141	IC138553	16.33	10.62	S
22	IC311079	6.72	1.89	R	142	IC310102	6.14	4.16	R
23	IC321856	18.03	7.24	MS	143	IC372745	21.60	12.8	S
24	IC335679	53.90	22.34	HS	144	IC310124	39.21	21.81	HS
25	IC336648	30.64	12.90	S	145	IC310120	5.55	2.77	R
26	IC347884	12.23	4.49	R	146	IC329445	13.77	8.53	MS
27	IC35076	10.00	2.5	R	147	CK	-	-	-
28	IC36692	60.86	32.60	HS	148	IC582705	3.57	1.27	R
29	IC36701	0	0	-	149	IC582721	0	0	-
30	IC36722	0	0	-	150	IC082281	6.69	2.39	R
31	IC384542	51.04	25.78	HS	151	IC082283	7.69	5.17	MS
32	IC398287	50.87	22.80	HS	152	IC082306	8.05	6.20	MS
33	IC401979	19.76	10.17	S	153	IC082285	17.16	12.5	S
34	IC402013	11.32	3.30	R	154	IC262760	5.35	3.12	R
35	IC415931	12.76	7.57	MS	155	IC274563	16.96	10.26	S
36	IC415939	0	0	-	156	IC107906	16.50	10.92	S
37	IC415955	48.07	21.39	HS	157	IC279316	0	0	-
38	IC415963	7.93	3.96	R	158	IC549925	5.31	2.92	R
39	IC416022	20.79	9.90	MS	159	IC107915	44.31	38.06	HS
40	IC416026	66.66	36.11	HS	160	IC278677	38.97	35.84	HS
41	IC416046	1.83	0.45	R	161	IC278678	13.93	9.95	MS
42	IC416053	9.52	4.08	R	162	IC278681	12.56	8.57	MS
43	IC416061	25.76	11.79	S	163	IC082308	14.47	9.04	MS
44	IC416065	13.63	6.81	MS	164	IC421928	15.62	12.63	S
45	IC416111	5.31	1.59	R	165	IC107371	9.84	2.46	R
46	IC416168	36.92	17.88	S	166	IC328499	10.37	7.31	MS
47	IC416408	13.41	4.87	R	167	IC355864	36.06	30.32	HS
48	IC443722	60.63	27.52	HS	168	IC266137	39.72	23.63	HS
49	IC443767	32.90	17.25	S	169	IC398279	7.98	2.37	R
50	IC445527	90.90	74.43	HS	170	IC398280	12.31	6.06	MS
51	IC469463	32.54	14.79	S	171	IC398298	1.40	0.82	R
52	IC469485	34.11	20.88	HS	172	IC585652	17.44	10.20	S
53	IC47797	3.139	0.78	R	173	IC281550	14.19	8.70	MS
54	IC527448	17.59	6.48	MS	174	IC393124	50.54	34.06	HS
55	IC528963	80.70	48.68	HS	175	IC393124	18.46	12.27	S
56	IC529202	0	0	-	176	IC282871	0	0	-
57	IC529222	2.52	0.63	R	177	IC573145	7.69	5.16	MS
58	IC529309	0	0	-	178	IC573157	-	-	-
59	IC529410	68.68	34.59	HS	179	IC573164	7.95	3.83	R
60	IC530051	0	0	-	180	IC430345	18.71	8.42	MS
61	IC530066	44.26	18.03	S	181	IC406697	4.91	2.15	R
62	IC530075	14.28	6.349	MS	182	IC564129	6.03	2.58	R
63	IC531233	0	0	-	183	IC524220	50.43	25.32	HS

(Contd. Part Table 1)

64	IC531275	4.61	1.69	R	184	IC356105	6.43	2.33	R
65	IC531820	9.18	4.86	R	185	IC356111	5.74	2.87	R
66	IC531950	29.31	17.67	S	186	IC3561113	9.93	5.27	MS
67	IC534300	46.60	30.82	HS	187	IC273982	9.52	3.57	R
68	IC534286	50.00	26.69	HS	188	IC279753	28.84	13.46	S
69	IC535470	38.33	19.58	S	189	IC589301	0	0	-
70	IC535396	20.83	6.94	MS	190	IC279825	0	0	-
71	IC335679	27.04	15.36	S	191	IC281563	54.63	32.40	HS
72	IC536139	7.27	5.75	MS	192	IC340956	45.50	27.54	HS
73	IC539313	-	-	-	193	IC145926	9.23	4.89	R
74	IC539305	22.72	9.41	MS	194	IC252358	-	-	-
75	IC539415	36.73	20.66	HS	195	IC145983	30	13.33	S
76	IC539593	23.18	14.13	S	196	IC138359	34.78	18.47	S
77	IC543280	0	0	-	197	IC138554	30.61	14.79	S
78	IC553110	9.89	6.04	MS	198	IC273946	1.13	0.56	R
79	IC73595	0	0	-	199	IC310041	18.75	10.93	S
80	IC542645	48.50	26.11	HS	200	IC398284	29.41	16.47	S
81	IC463384	28.71	15.45	S	201	IC444246	44.65	34.43	HS
82	IC556507	0	0	-	202	IC564106	30.09	24.02	HS
83	IC556999	34.61	26.28	HS	203	IC0138631	49.04	42.03	HS
84	IC112111	55.31	30.85	HS	204	IC0532689	22.05	11.76	S
85	IC145237	7.93	5.55	MS	205	IC0111801	7.65	6.55	MS
86	IC252431	23.28	12.32	S	206	IC0112053	43.95	36.67	HS
87	IC252434	3.53	0.88	R	207	IC0296443	27.02	20.94	HS
88	IC279228	32.07	20.75	HS	208	IC0296469	72.41	64.43	HS
89	IC321907	51.61	30.80	HS	209	IC0524284	40.94	35.12	HS
90	IC321916	61.60	32.58	HS	210	IC0616578	8.60	6.18	MS
91	IC416108	8.94	3.89	R	211	IC0296603	0	0	-
92	IC529681	4.25	1.59	R	212	EC597821	9.42	6.15	MS
93	IC534974	15.31	8.22	MS	213	EC362041	2.55	1.9	R
94	IC553116	7.89	2.30	R	214	EC105998	12.72	10.45	S
95	IC578005	11.76	5.88	MS	215	EC598061	-	-	-
96	IC566636	4.081	1.02	R	216	IC0128201	32.85	26.42	HS
97	NBPG7929	67.66	37.59	HS	217	IC0128236	61.66	50.13	HS
98	IC0534139	2.77	0.69	R	218	IC0128242	69.31	56.53	HS
99	IC0534222	0	0	-	219	IC0303072	0	0	-
100	IC0534359	68.31	46.28	HS	220	IC0296308	86.2069	74.31	HS
101	IC0534403	23.80	13.33	S	221	IC0443766	0	0	-
102	IC0534404	51.72	29.88	HS	222	IC0393877	9.52381	7.99	MS
103	IC0534428	40.77	23.05	HS	223	IC0443740	0	0	-
104	IC0534503	64.13	37.06	HS	224	IC0443747	0	0	-
105	IC0534646	13.11	6.55	MS	225	IC0438390	8.04	4.31	R
106	IC0534699	36.47	21.54	HS	226	IC0528118	10.19	7.48	MS
107	IC0535052	44.82	17.95	S	227	IC0073206	0	0	-
108	IC336494	33.73	18.67	S	228	IC0445595	34.74	28.38	HS
109	CK	79.54	54.54	HS	229	IC0519900	32.03	27.61	HS
110	IC598261	25.00	10.93	S	230	IC0566544	26.44	19.42	S
111	IC128386	18.18	8.76	MS	231	IC0574481	25.61	19.03	S
112	IC261937	14.21	9.19	MS	232	IC0598225	29.71	20.08	HS
113	IC261397	5.20	2.16	R	233	IC0598248	0	0	-
114	IC619437	66.66	41.14	HS	234	3556295	0	0	-
115	IC619450	77.41	51.61	HS	235	3556296	0	0	-
116	IC426303	52.40	34.17	HS	236	3556297	0	0	-
117	IC324561	6.25	2.99	R	237	5099329	0	0	-
118	IC384532	59.53	36.67	HS	238	5099326	0	0	-
119	IC384537	79.83	46.16	HS					
120	IC138487	16.41	6.71	MS					

\*Coefficient of infection; R-Resistant; MR-Moderately Resistant; S-Susceptible; HS-Highly susceptible

\*Based on the coefficient of infection, genotypes were categorized into highly resistant (COI=0), resistant (COI=0.1-5), moderately susceptible (COI=5.1-10), susceptible (COI=10.1-20), and highly susceptible (COI=>20).

## RESULTS AND DISCUSSION

In the present investigation, 238 bread wheat genotypes were procured from ICAR-NBPGR, New Delhi and were screened for two years

**Table 2:** Screening bread wheat germplasm against Karnal bunt of wheat under net house conditions (2023-24)

Sl. No	Accession numbers	% KB incidence	*COI	Disease response	Sl. No.	Accession numbers	% KB Incidence	*COI	Disease response
1	IC111687	10.44	5.08	MS	121	IC384528	28.23	11.48	S
2	IC111738	19.85	11.21	S	122	IC384555	15.63	6.65	MS
3	IC111822	10.23	2.56	R	123	IC532086	5.23	1.93	R
4	IC111914	16.78	7.78	MS	124	IC532238	15.46	7.25	MS
5	CHK1	2.63	0.65	R	125	IC5322489	11.25	6.23	MS
6	IC128211	33.12	13.81	S	126	IC532262	37.85	16.78	S
7	IC128388	61.84	42.27	HS	127	IC532149	14.04	6.58	MS
8	IC138384	25.67	9.23	MS	128	IC532099	17.45	7.78	MS
9	IC138419	65.12	37.23	HS	129	IC532414	32.15	13.47	S
10	IC138426	24.23	10.73	S	130	IC079009	13.49	8.79	MS
11	IC252487	16.25	5.73	MS	131	IC262866	11.11	5.56	MS
12	IC252660	85.45	58.64	HS	132	IC279876	0	0	-
13	IC252824	0.00	0.00	-	133	IC361690	15.26	6.65	MS
14	IC252844	6.18	3.73	R	134	IC381179	10.74	5.24	MS
15	IC252853	9.67	5.25	MS	135	IC078988	19.81	10.38	S
16	IC252876	18.98	9.03	MS	136	IC082221	21.45	10.27	S
17	IC252928	33.33	8.33	MS	137	IC082225	46.99	34.64	HS
18	IC296437	6.65	2.56	R	138	IC423446	11.74	5.78	MS
19	IC296530	11.13	5.23	MS	139	IC082279	33.25	15.46	S
20	IC296538	16.15	11.15	S	140	IC082302	15.74	7.42	MS
21	IC296743	12.38	7.14	MS	141	IC138553	43.40	19.81	S
22	IC311079	2.44	1.22	R	142	IC310102	12.24	5.26	MS
23	IC321856	11.83	5.73	MS	143	IC372745	23.15	13.82	S
24	IC335679	45.78	21.75	HS	144	IC310124	17.95	13.46	S
25	IC336648	31.25	11.90	S	145	IC310120	8.46	5.74	MS
26	IC347884	27.20	14.00	S	146	IC329445	6.06	5.30	MS
27	IC35076	11.78	2.73	R	147	CK	-	-	-
28	IC36692	55.56	31.25	HS	148	IC582705	2.45	1.41	R
29	IC36701	12.50	3.13	R	149	IC582721	1.67	0.42	R
30	IC36722	55.56	15.28	S	150	IC082281	7.83	5.46	MS
31	IC384542	48.23	23.89	HS	151	IC082283	9.78	5.32	MS
32	IC398287	0.00	0.00	-	152	IC082306	9.45	6.68	MS
33	IC401979	18.79	10.85	S	153	IC082285	21.56	13.20	S
34	IC402013	12.12	7.58	MS	154	IC262760	7.48	6.23	MS
35	IC415931	12.87	9.78	MS	155	IC274563	17.26	9.45	MS
36	IC415939	16.67	4.17	R	156	IC107906	18.76	8.75	MS
37	IC415955	47.43	22.75	HS	157	IC279316	0	0	-
38	IC415963	10.25	5.46	MS	158	IC549925	11.32	6.60	MS
39	IC416022	22.26	8.70	MS	159	IC107915	35.78	32.12	HS
40	IC416026	64.23	33.56	HS	160	IC278677	33.46	26.49	HS
41	IC416046	2.23	1.45	R	161	IC278678	16.25	8.63	MS
42	IC416053	25.00	14.06	S	162	IC278681	13.75	7.45	MS
43	IC416061	9.91	6.47	MS	163	IC082308	13.49	7.74	MS
44	IC416065	15.62	6.75	MS	164	IC421928	15.64	6.70	MS
45	IC416111	6.21	1.78	R	165	IC107371	11.46	5.16	MS
46	IC416168	32.23	15.28	S	166	IC328499	33.33	8.33	MS
47	IC416408	12.65	6.84	MS	167	IC355864	35.74	26.85	HS
48	IC443722	17.43	9.40	MS	168	IC266137	25.22	15.00	S
49	IC443767	35.25	13.25	S	169	IC398279	12.42	6.53	MS
50	IC445527	34.48	27.59	HS	170	IC398280	14.25	6.65	MS
51	IC469463	40.94	16.67	S	171	IC398298	7.41	2.31	R
52	IC469485	32.11	22.25	HS	172	IC585652	22.22	5.56	MS
53	IC47797	1.81	0.60	R	173	IC281550	17.45	12.36	S
54	IC527448	24.14	12.93	S	174	IC393124	45.23	31.26	HS
55	IC528963	32.74	21.90	HS	175	IC393124	16.45	13.78	S
56	IC529202	5.26	2.63	R	176	IC282871	0	0	-
57	IC529222	9.77	5.95	MS	177	IC573145	8.56	5.46	MS
58	IC529309	0	0	-	178	IC573157	25.23	14.25	S
59	IC529410	54.55	18.18	S	179	IC573164	12.48	5.28	MS
60	IC530051	0	0	-	180	IC430345	45.23	22.24	HS
61	IC530066	38.89	29.17	HS	181	IC406697	13.73	13.24	S
62	IC530075	15.28	7.45	MS	182	IC564129	8.78	5.48	MS
63	IC531233	0	0	-	183	IC524220	10.45	6.25	MS
64	IC531275	2.31	0.58	R	184	IC356105	15.79	7.46	MS
65	IC531820	4.85	2.73	R	185	IC356111	12.78	5.46	MS
66	IC531950	11.11	2.78	S	186	IC3561113	14.64	6.78	MS

(Contd. Part Table 2)

67	IC534300	21.18	11.47	S	187	IC273982	16.78	5.46	MS
68	IC534286	14.29	6.25	MS	188	IC279753	32.45	16.73	S
69	IC535470	35.23	18.46	S	189	IC589301	0	0	-
70	IC535396	22.45	7.25	MS	190	IC279825	0	0	-
71	IC335679	25.78	14.56	S	191	1C281563	46.58	23.56	HS
72	IC536139	8.45	6.87	MS	192	1C340956	33.29	23.46	HS
73	IC539313	2.08	1.30	R	193	JC145926	17.23	7.28	MS
74	IC539305	35.71	11.90	S	194	IC252358	-	-	-
75	IC539415	63.41	42.68	HS	195	IC145983	28.63	14.23	S
76	IC539593	22.45	7.85	MS	196	IC138359	32.46	17.86	S
77	IC543280	0	0	-	197	IC138554	27.89	14.23	S
78	IC553110	10.27	6.65	MS	198	IC273946	3.25	2.12	R
79	IC73595	0	0	-	199	IC310041	16.67	10.42	S
80	IC542645	27.18	8.74	MS	200	IC398284	24.26	17.56	S
81	IC463384	30.25	17.45	S	201	IC444246	32.42	24.59	HS
82	IC556507	7.59	1.90	R	202	IC564106	24.78	21.63	HS
83	IC556999	35.62	28.27	HS	203	IC0138631	36.85	35.78	HS
84	IC112111	22.60	16.83	S	204	IC0532689	22.46	11.58	S
85	IC145237	24.11	14.51	S	205	IC0111801	11.78	5.46	MS
86	IC252431	24.56	13.58	S	206	IC0112053	22.22	7.14	MS
87	IC252434	18.45	11.11	S	207	IC0296443	24.78	21.76	HS
88	IC279228	35.47	18.75	S	208	IC0296469	45.78	33.56	HS
89	IC321907	11.95	5.82	MS	209	IC0524284	32.68	22.58	HS
90	IC321916	54.23	25.23	HS	210	IC0616578	13.46	6.56	MS
91	IC416108	8.89	5.26	MS	211	IC0296603	16.30	7.61	MS
92	IC529681	5.26	3.62	R	212	EC597821	46.60	35.01	HS
93	IC534974	15.46	5.26	MS	213	EC362041	5.75	2.06	R
94	IC553116	34.58	25.37	HS	214	EC105998	16.67	6.60	MS
95	IC578005	16.25	8.45	MS	215	EC598061	-	-	-
96	IC566636	5.12	1.46	R	216	IC0128201	28.98	23.45	HS
97	NBPG7929	45.23	36.24	HS	217	IC0128236	17.95	9.62	MS
98	IC0534139	12.62	6.55	MS	218	IC0128242	34.65	28.45	HS
99	IC0534222	0	0	-	219	IC0303072	10.08	7.56	MS
100	IC0534359	56.27	36.89	HS	220	IC0296308	56.23	35.46	HS
101	IC0534403	25.63	12.75	S	221	IC0443766	13.08	7.38	MS
102	IC0534404	21.23	13.69	S	222	IC0393877	18.02	11.49	S
103	IC0534428	66.67	16.67	S	223	IC0443740	4.39	1.97	R
104	IC0534503	28.17	20.07	S	224	IC0443747	8.33	2.08	R
105	IC0534646	44.28	36.78	HS	225	IC0438390	13.25	5.78	MS
106	IC0534699	22.22	13.89	S	226	IC0528118	12.78	6.20	MS
107	IC0535052	28.26	21.20	HS	227	IC0073206	9.77	5.23	MS
108	IC336494	28.26	14.13	S	228	IC0445595	26.88	14.25	S
109	CK	15.49	5.11	MS	229	IC0519900	20.00	6.67	MS
110	IC598261	12.40	10.47	S	230	IC0566544	25.46	16.45	S
111	IC128386	17.45	7.48	MS	231	IC0574481	36.78	18.10	S
112	IC261937	23.30	13.83	S	232	IC0598225	63.64	34.09	HS
113	IC261397	12.50	6.88	MS	233	IC0598248	42.86	21.43	HS
114	IC619437	45.26	35.28	HS	234	3556295	0	0	-
115	IC619450	35.28	25.49	HS	235	3556296	0	0	-
116	IC426303	45.79	26.59	HS	236	3556297	0	0	-
117	IC324561	26.53	11.22	S	237	5099329	0	0	-
118	IC384532	55.48	36.15	HS	238	5099326	28.33	15.24	S
119	IC384537	32.89	23.45	HS					
120	IC138487	13.56	5.93	MS					

\*Coefficient of infection; R-Resistant; MR-Moderately Resistant; S-Susceptible; HS-Highly susceptible

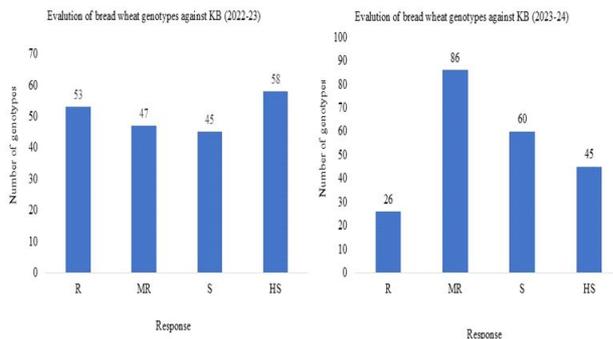
(2022-23 and 2023-24) under artificial inoculation conditions. During the 2022-23, a high incidence of Karnal bunt was observed. The COI ranged from 0.45 to 74.43% and the percentage of disease incidence varied from 1.13 to 90.9. Out of 238 genotypes, fifty-three genotypes (IC111822, CHK1, IC128388, IC252853, IC252928, IC296437, IC296530, IC296743, IC311079, IC347884, IC35076, IC402013, IC415963, IC416046, IC416053, IC416111,

IC416408, IC47797, IC529222, IC531275, IC531820, IC252434, IC416108, IC529681, IC553116, IC566636, IC0534139, IC261397, IC324561, IC532086, IC532149, IC381179, IC078988, IC423446, IC310102, IC310120, IC582705, IC082281, IC262760, IC549925, IC107371, IC398279, IC398298, IC573164, IC406697, IC564129, IC356105, IC356111, IC273982, IC145926, IC273946, EC362041,



**Fig.1:** Disease scoring scale for Karnal bunt of wheat (Aujla *et al.*, 1989)

IC0438390) were found resistant, 49 genotypes were moderately susceptible, 44 genotypes were susceptible, and 58 were highly susceptible (Table 1, Fig. 2). In the 2023-24, moderate to high incidence of Karnal bunt was assessed and the COI ranged from 0.42 to 37.23%. Out of 238 genotypes, 26 genotypes were found resistant, (IC111822, CHK1, IC252844, IC296437, IC311079, IC35076, IC36701, IC415939, IC416046, IC416111, IC47797, IC529202, IC531275, IC531820, IC539313, IC556507, IC529681, IC566636, IC532086, IC582705, IC582721, IC398298, IC273946, EC362041, IC0443740, IC0443747), 86 genotypes were moderately susceptible, 60 genotypes were susceptible, and 45 were highly susceptible (Table 2, Fig.2 and Fig.3). Subsequent comparative analysis of two-year (2022-23 and 2023-24) data of 238 bread wheat genotypes, only 17 genotypes (IC111822, CHK1, IC296437, IC311079, IC35076, IC416046, IC416111, IC47797, IC531275, IC531820, IC529681, IC532086, IC566636, IC582705, IC398298, IC273946 and EC362041) were found to show the stable resistance to Karnal bunt disease of wheat.



**Fig. 2 :** Response of bread wheat genotypes for Karnal bunt of wheat

Internationally, KB genetic resistance is needed for the free flow of the global wheat trade. The development of resistant cultivars has been also hampered due to limited resistant genetic sources and confounding environmental effects on the quantitative nature of resistance (Sharma *et al.* 2004). Through a cross of two Karnal bunt



**Fig. 3:** Karnal bunt resistant and susceptible bread wheat genotypes

resistant lines (HD29 and W485), Sharma *et al.* (2004) were formed a KB-resistant wheat stock (KBRL8, KBRL14, KBRL16, KBRL22 and KBRL24). They employed KBRL22 as a donor for KB-free trait introgression into the most extensively cultivated variety PBW343. Singh *et al.* (2003) procured KB-resistant sources of wheat from Advanced Varietal Trials and other sources like CIMMYT. They tested them at KB hot-spot multi-locations (Punjab, Himachal Pradesh, Haryana, New Delhi and Uttar Pradesh states in India) under artificially inoculated conditions during 1990-91 and 1993- 94. Out of 66 entries, 18 were resistant lines, namely HD 29, HD 30, HD 2385, RAJ 2296, WL 1786, WL 6975, WL 7247, HW 502, PBW 34, PBW 225, W 285, W 382, W 388, W 485, DWL 5010, ND 589, ND 602 and HP 1531. PBW 34 and PBW 225 were released as varieties. HD 29 and HD 30 had already been registered by the National Bureau of Plant Genetic Resources, New Delhi, as INGR99011 and INGR99012, respectively. KB-resistant lines of durum wheat (D482,D873,D879, D895) and triticale (TL2807) from Punjab Agricultural Research Institute, Ludhiana were also registered with NBPGR, New Delhi (Sharma *et al.* 2007). In conclusion, the earlier and our studies showed that high diversity for Karnal bunt resistance exists in wheat genotypes. The resistant genotypes can be used to develop an improved cultivar with the resistance to Karnal bunt of wheat and there is a continuous need to identify new resistant sources against Karnal bunt.

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## DECLARATION

Conflict of Interest. Authors declare no conflict of interest.

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