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Screening of putative resistant sources against Indian and exotic isolates of *Albugo candida* inciting white rust in rapeseed-mustard

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Abstract

Screening of worldwide *Brassica juncea* (L.) Czern & Coss. germplasm for horizontal resistance against *Albugo candida* (Pers. ex. Lev) Kuntze isolates virulent in India and Canada revealed that almost all the important varieties being grown in India are susceptible to white rust disease. All lines of *B. juncea* var. Cutlass showed resistant response to the mixture of *A. candida* isolates derived from *B. juncea* and *B. rapa* except 2V (Canadian isolate). When the same lines inoculated again with a mixture of these isolates including 2V, these lines expressed high susceptibility to white rust. Further, three lines derived from var. Cutlass selected on the basis of their earlier resistant reaction to the mixture of isolates RESJ-998, RESJ-1004 and RESJ-1005 were tested for their response to 2V alone. Three plants from RESJ-1052 and one plant each from RESJ-1004, RESJ-1005, RESJ-1033 and RESJ-1051 were found to be resistant to all the Indian isolates as well as 2V. These resistant sources with combined resistance to different white rust isolates proved to be putative donors for oilseed Brassica crop improvement programmes.

Keywords: *Albugo candia isolates, differential response, resistant sources*

Introduction

Rapeseed-mustard comprise the most important edible oilseed crops in India. White rust incited by *Albugo candida* (Pers. ex. Lev) Kuntze. affects these crops in India as well as other countries and is one of the major constraints for their low productivity (Saharan and Verma, 1992, Rimmer *et al.*, 2000). *A. candida* exhibits specialization on different cruciferous species and on cultivars within species (Petrie, 1988, Mathur *et al*., 1995, Verma *et al*., 1999). The pathogen can infect all the above ground plant parts and cause extensive distortion, hypertrophy, hyperplasia and sterility culminating in systemic "staghead" of the inflorescence often in association with downy mildew (*Hyaloperonospora brassicae*) (Goyal *et al*., 1996, Awasthi *et al*., 1997). Depending on the severity of infection, the yield losses caused by white rust or a mixture of white rust and downy mildew, range between 17% to 60%, (Berneir, 1972; Harper & Pittman, 1974; Petrie & Vanterpool, 1994; Bains & Jhooty, 1979; Kolte, 1996; Verma and Bhowmik, 1989; Saharan *et al.*, 1990). While resistance to downy mildew in *Brassica* has been developed (Nashaat *et al.*, 1998), most of the Indian cultivars are still susceptible to white rust. Therefore, the present investigation focuses on generation of putative sources that could be crossed to combine resistance to Indian and Canadian isolates of *A. candida* in a line that would be suitable for Indian conditions.

Materials and Methods

The present investigation was carried out in spore-free, controlled environment glasshouse facilities at Rothamsted Research, Harpenden, UK under Indo-UK Collaboration on Oilseed Crops (Rapeseed-Mustard) Phase II 1998 to 2007.

Plant Material: Forty-five *B. juncea* accessions were collected from India, China, Bangladesh and Canada. Untreated seeds were sown 5mm deep in 50 x 50 mm Jiffy pots containing peat-based compost mix and placed inside a propagator (570 x

290 x 210 mm). Approximately 5 mm diameter hole was made in the base of the jiffy pots to allow for excess water drainage. Each propagator contained 12 accessions with five jiffy pots for each in two replications including three susceptible controls. The seeds were thinned from initial six-seven sowing to four prior to inoculation to maintain a uniform number of seedlings per pot at the same growth stage. After sowing, the propagators were immersed in water filled trays for one hour to allow for absorption of water through the base. The holes at the base of each propagator were cleared of debris for air passage when placed on the airflow bench to provide spore free environment in the glasshouse. The air exhausted through the two ventilators on the propagator lids and the junction between the lids and the propagator base. After four to five days, each propagator was watered again in the same manner for 30 minutes to maintain proper soil moisture prior to inoculation. The propagators were then returned to the airflow bench (Fig. 1a).

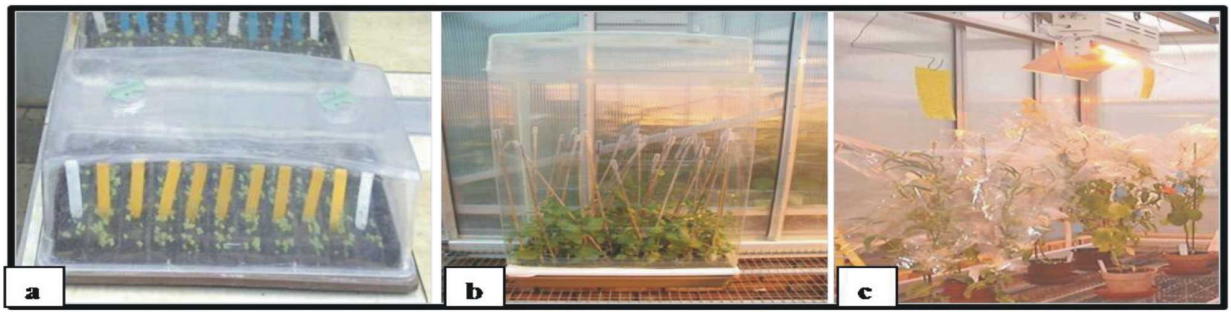

Fig. 1: a. Plants raised under spore-free conditions; b. Screening of selected plants at juvenile stage; c. Selected resistant plants at flowering stage in quarantine glasshouse

Provenance and maintenance of fungal isolates:

The single pustule isolates of *A. candida* derived from India (10), Canada (2) and UK (1) were referred as IA05, IA06, IA09, IA10, IA11P, IA11R, 2A and 2V and from *B. rapa* as IA07, IA08 and IA12 (Table 1). These isolates were maintained on seven-day-old seedlings of respective susceptible host accessions, PPBJ-1 (*B. juncea*) and RESR-397 (*B. rapa*).

Seedlings were raised from untreated seeds sown in 5x5cm jiffy pots with moist sterilized soil-less compost (manufactured by Jiffy A/S Denmark) with moist sterilized soil-less compost. These pots containing four to six seeds per pot were placed in a plant propagator under spore free conditions in glass house at 18°C ± 2°C (Jenkyn *et al*, 1973; Nashaat & Rawlinson, 1994) with supplementary lights to maintain a 16 hour light/ 8hr dark day/night cycle.

The inoculum preparation was carried out under aseptic conditions inside a Class II Laminar flow cabinet. Sporangial suspension of *A. candida* was prepared in a glass vial containing 20 ml sterilized distilled water (SDW). Profusely sporulating cotyledons/leaves from the previous stock (infected leaf pieces stored in deep freezer between -20 to -30°C) or from fresh leaves 12 days after inoculation, were put in the vial, closed tightly and shaken vigorously on a vortex to release the sporangia into suspension. The sporangial suspension was observed in a haemocytometer under the microscope and the concentration was adjusted to 1 x 10^4 sporangia/ml. Each sporangium bursts to release eight zoospores, to give a concentration of 8 x 10^4 zoospores/ml.

Seedlings were inoculated seven days after sowing by placing two 5µl droplets of sporangial suspension on each cotyledon using a Gilsons micropipette (drop inoculation) and seedlings were sprayed to run off with sporangial suspension using an atomizer (spray inoculation). After inoculation, the pots were covered with clear plastic lids, and the ventilators and margins were sealed with insulation tape to allow the relative humidity (RH) to increase to 100%. The seedlings were then placed in a growth chamber at 16°C, alternate dark and light cycle of 8 hr and 16 hr, respectively, at 70-120 µmol/m/s irradiations for 12 days to reach peak sporulation.

Table 1: List of *A. candida* isolates

Isolate Code	Species of Origin	Maintenance Cultivar	Culture Type*	Date Collected/ Derived	Source/ Geographic Origin	Cultivar of Origin	Previous Notes
IA05	*B. juncea*	PPBJ-1	FI	13-03-98	Pantnagar, India	Krishna	
IA06	*B. juncea*	PPBJ-1	FI	18-12-99	Pantnagar, India	Mustard (Kranti)	Less virulent
IA07	*B. rapa*	RESR-263	FI	18-12-99	Pantnagar, India	Toria (PT-303)	Virulent
IA08	*B. rapa*	RESR-263	FI	18-12-99	Pantnagar, India	Yellow Sarson (FTPYS)	Unknown
IA09	*B. juncea*	PPBJ-1	FI	06-10-00	Chitradurga, Karnataka, India	JM - 1	
IA10	*B. juncea*	PPBJ-1	FI	13-02-01	Bihar, India	Bardan	Also virulent on *B. rapa*
IA11P	*B. juncea*	PPBJ-1	FI	06-02-02	Bharatpur, India	n/a	Pinhead pustules
IA11 R	*B. juncea*	PPBJ-1	FI	06-02-02	Bharatpur, India	n/a	Ring type pustules
IA11	*B. juncea*	PPBJ-1	FI	06-02-02	Bharatpur, India	n/a	Mixture of IA11P and IA11R
IA12	*B. rapa*	RESR-263	FI	06-02-02	Bharatpur, India	n/a	
2A	*B. juncea*	Burgonde	SPI	n/a	Agriculture Canada, Saskatoon	n/a	
2V	*B. juncea*	Cutlass	SPI	n/a	Agriculture Canada, Saskatoon	n/a	
Ac117	*B. oleracea*	Maris Kestrel	n/a	04-07-02	Cornwall, UK	Black Kale	From Nick Gunn, HRI - Wellesbourne

*SPI= Single Pustule Isolate; FI = Field Isolate

Test inoculation: The seedlings were grown under the same conditions and inoculated using the same method as used for isolates maintenance. For preparation of sporangial suspension containing more than one isolate, the concentration (conc.) was adjusted using the formula: conc.= (number of isolates/ 2) x original sporangial conc. For e.g. six isolates combination in one suspension= (6/2) x 1 x 10^4 = 3 x 10^4 sporangia/ml giving a zoospore concentration of 2.4 x 10^5 zoospores/ml. Approx. 20ml and 40ml of spore suspension were used for spray inoculation on the seedlings at five to seven leaf stage plants respectively, in each propagator.

Scoring, disease assessment and selection: Infection phenotypes were recorded after 12 days of incubation using scoring system (Leckie *et al.*, 1996). The selected resistant plants were inoculated further at juvenile stage between 25-30 days after sowing (DAS) and at 40-45 DAS. After scoring, seedlings expressing Interaction Phenotype (IP) NN to FN were selected for further testing at five to seven leaf stage (25 to 30 DAS) and at flowering stage (40 to 45 DAS) by further similar inoculation as earlier, each time retaining only the resistant plants (Fig. 1b).

The susceptible plants were discarded after scoring and the resistant plants were raised in quarantine glasshouse at Rotamsted Research, UK (Fig. 1c). These plants were used for crossing and selfing to incorporate *A. candida* resistance gene (s) into lines suitable for Indian conditions. Cryovac supermicro plastic bags manufactured by Sealed Air Ltd., Cambs, UK, were used to cover inflorescences to facilitate self pollination and prevent cross-pollination. The selfed seeds were harvested for testing to confirm the inheritance of resistance.

Table 2: *Brassica juncea* accessions tested against *Albugo candida* isolates

Accession	RES No	Original seed source	Parentage	Seed Colour	Maturity Group**	Height Group***	Remarks
Kranti	RESJ-903	India (GBPUAT)	selection from Varuna	brown	medium	tall	
Krishna	RESJ-902	India (GBPUAT)	selection from Varuna	brown	medium	tall	
Varuna	RESJ-900	India (GBPUAT)	selection from Varansi	brown	medium	tall	
PPBJ-1	RESJ-901	India (GBPUAT)	selection from local	brown	medium	dwarf	highly susceptible to WR, DM & AB
BEC-1	RESJ-904	India (GBPUAT)		brown			
BEC-7	RESJ-906	India (GBPUAT)		brown			
BEC-23	RESJ-909	India (GBPUAT)		brown			
PYSR-7	RESJ-910	India (GBPUAT)		dull yellow			
PYSR-9	RESJ-911	India (GBPUAT)		dull yellow			
KL-2	RESJ-913	India (GBPUAT)		brown			
RL-1359	RESJ-920	India (NRCRM)	RLM514 X Varuna	brown	medium	mediu m	tolerant to aphid
VSL-5	RESJ-921	India (NRCRM)	Varuna X Synthetic juncea	brown	medium	tall	
PBR-91	RESJ-922	India (NRCRM)	(RLM511 X PR18) X GM-1	brown	late	tall	
RLM-619	RESJ-923	India (NRCRM)	G.rays mutant X RL 18	brown	late	tall	moderately res. to aphid & shattering
CS-52	RESJ-924	India (NRCRM)	selection from DIAR-343	brown	late	tall	tolerant to saline & alkaline soils
Seeta	RESJ-926	India (NRCRM)	selection from local	brown	early	dwarf	escape from drought
PR-8988	RESJ-928	India (NRCRM)	PR8611 X Varuna	brown	medium	tall	
RH-8812 [Laxmi]	RESJ-929	India (NRCRM)	PR-15 X RH-30	brown	late	tall	
RH-8113	RESJ-930	India (NRCRM)	T-59 X RC-781	brown	late	tall	moderately resistant to *Alternaria* Blight
RH-30	RESJ-931	India (NRCRM)	selection from P26/3-1	brown	late	tall	resistant to shattering
RH-819	RESJ-932	India (NRCRM)	Prakash X Bulk Pollen	brown	late	tall	resistant to drought
RH-781	RESJ-933	India (NRCRM)	(RL18 x P26/3-1) X RL-18	brown	late	tall	
BIO-902	RESJ-934	India (NRCRM)	Somaclone fom Varuna	brown	medium	tall	resistant to lodging & shattering
PCR-7 [Rajat]	RESJ-935	India (NRCRM)	selection from JMG36-6	brown	medium	tall	tolerant to drought
Rohini	RESJ-936	India (NRCRM)	selection from Varuna	brown	medium	tall	

Vaibhav	RESJ-937	India (NRCRM)	Derived from biparental cross	brown	medium	tall	
SEJ-2	RESJ-939	India (NRCRM)	*B. juncea*X Synth. *B. juncea*	brown	early	mediu m	early maturing mustard variety
Varadan	RESJ-940	India (NRCRM)	Derivatves of biparental crosses	brown	medium	tall	suitable for late sown(November planting) in India
RN-393 [Aravali]	RESJ-941	India (NRCRM)	Krishna X RS-50	brown	medium	tall	drought tolerant
Pusa Bold	RESJ-942	India (NRCRM)	Varuna X BIC-1780	brown	medium	tall	bold seeded & high yielding variety
Pusa Bahar	RESJ-943	India (NRCRM)	(PR28 x Varuna) X (PR30 X T6342)	brown	medium	tall	
Sarma	RESJ-944	India (NRCRM)	Varuna X B-85	brown	early	mediu m	
T-6342	RESJ-945	India (NRCRM)	selection from local	brown	late	tall	moderately resistant to aphid
Jataya Sarson	RESJ-946	India (NRCRM)					
Sanjucta Asech	RESJ-947	India (NRCRM)	TM 4 X RK 2	brown	early	dwarf	
TM-2	RESJ-948	India (NRCRM)	Gamma ray mutant from RL18	brown	early	mediu m	less susceptible to AB & Powdery mildew
TM-4	RESJ-949	India (NRCRM)	Varuna X TM-1	yellow	early	mediu m	less susceptible to AB & Powdery mildew
Rai	RESJ-916	Bangladesh		brown			
Daulat	RESJ-917	Bangladesh		brown			
Chang Yang Huang Jie	RESJ-950	(China-HAU)	S2 of RESJ-294 (DM Group C)	yellow			resistant to DM in field test at Pantnagar, INDIA
Chang Yang Huang Jie	RESJ-951	(China-HAU)	S2 of RESJ-295 (DM Group C)	dull yellow			resistant to DM & WR in field test at Pantnagar, INDIA
Yi Meng Feng Wei Zi	RESJ-952	(China-HAU)	S2 of RESJ-140 (DM Group P)	brown			resistant to DM & WR in field test at Pantnagar, INDIA
Landrace/BG RC-46323	RESJ-953	FAL	S2 of RESJ-177 (DM Group J)	light brown			resistant to WR in field test at Pantnagar, INDIA
Burgonde	RESJ-918	Canada (Rimmer)		brown			suscept. to CANADIAN & INDIAN isolates of WR
Cutlass	RESJ-919	Canada (Rimmer)		dull yellow			resistant to INDIAN ISOLATES of WR but suscep. to CANADIAN

CV = cultivated variety in India; ***** Seed Size: Small (< 3 g); Medium (3 to 4 g) and Bold (> 4 g); ****** Maturity Groups: Early (< 130 days); Medium (130 to 140 days) and Late (> 140 days); ******* Plant Height Groups: Dwarf (< 1 m); Medium (1 m to 1.5 m) and Tall (> 1.5 m);

Scores of different interaction phenotype classes (Leckie *et al*., 1996)

Interaction Phenotype (IP)	Host response	Pathogen growth	Disease Score	
NN	No response	No sporulation	0	
(F)N	Light necrotic flecking	No sporulation (Figure 8)	1	
FN	Heavy necrotic flecking	No sporulation	2	
S1	Any host response	Minute pustule on upper surface of cotyledon (*mp*)	3	
S2	Any host response	Few (*FP*) or numerous pustules (*NP)* on lower surface of cotyledon	4	5
S3	Any host response	Large scattered *(LP)* or coalescing pustules *(CP)* on lower surface of cotyledon (Figure 9)	6	7

Thirty-four S_1 progenies derived from 17 original accessions were again screened similarly, at seedling stage to confirm resistance against highly virulent Canadian isolate 2V. Plants found resistant were selected and screened again at juvenile stage.

Results and discussions

Screening of *B. juncea* var. Cutlass lines against 11 *A. candida* isolates: A few resistant plants (interaction phenotype NN to FN) from forty-five *B. juncea* accessions (Table 2) were identified, which needed further confirmation for resistance. Previous experiments have shown that *B. juncea* var. Cutlass showed uniform resistance to Indian *A. candida* isolates IA05, IA05B, IA06 and Canadian isolate 2A (Shukla, 2000). Later it was also found to be resistant to the other two Indian isolates IA09 and IA10 but it showed to be susceptibility to isolate 2V from Canada (Rimmer and Buchwaldt, 1995; Sachan, 2001). However, Sachan (2001) found that four percent of the Cutlass population was resistant to a mixture of six isolates (IA05, IA06, IA09, IA10, 2A and 2V). Therefore, the original population of var Cutlass included three S_1 lines of Cutlass (resistant to mixture of six isolates) along with three controls were screened against different isolates of *A. candida*.

All lines of var. Cutlass including the original population showed resistant responses to the mixtures of seven isolates derived from *B. juncea* and three isolates derived from *B. rapa* (Table 3). However, when these plants were inoculated again with a mixture of all the above isolates including 2V, the susceptible plants were 92 to 100 per cent. Only three per cent of RESJ-1005 and seven per cent of RESJ-998 population was found susceptible. Eighty-one per cent of the population of RESJ-1004 was found susceptible (Table 4 and Fig. 2). This indicates that the increase in susceptibility is due to high virulence/aggressiveness of isolate 2V. In addition fourteen plants from three lines derived from var. Cutlass that had been selected for resistance to the mixture of isolates (RESJ-998, RESJ-1004 and RESJ-1005) were also tested for their response to isolate 2V alone. One plant from RESJ-1004 and one plant from RESJ-1005 were selected for resistance to all Indian isolates and 2V (Table 5).

Confirmation of resistance in the progeny of lines of *B. juncea* accessions selected for resistance to *A. candida* isolate 2V: Some of the *B. juncea* accessions collected from India and China have been found to be less susceptible to isolates 2A and 2V from Canada than Indian isolates (Shukla, 2000). To confirm resistance in ndian *B. juncea* accessions against isolate 2V, screening of thirty-four S_1 progenies derived from 17 original accessions at seedling stage revealed eight lines (RESJ-1033, RESJ-1034, RESJ-1036, RESJ-1042, RESJ-1044, RESJ-1051, RESJ-1052 and RESJ-1057) expressing an interaction phenotype of NN to FN ranging from 3.0 to 45 per cent at the seedling stage. All other lines were found susceptible (Table 6 and 7). Three plants from RESJ-1052 recorded as resistant, one from RESJ-1033 and one from RESJ-1051 as tolerant against isolate 2V after inoculation and incubated for 12 days. The plants from RESJ-1033 and RESJ-1051 were resistant at the cotyledonary

Table 3: Response of seedlings of selfed *B. juncea* var. Cutlass lines to dual inoculation with a mixture of isolates of *A. candida* derived from *B. juncea*[1] on one cotyledonary leaf and a mixture of isolates derived from *B. rapa*[2] on the second cotyledonary leaf

Dual Inoculation (BJ & BR)	Number of plants	Percentage of plants expressing Interaction Phenotype*												Disease Index**			
		NN		(F)N		FN		S1		S2		S3		BJ		BR	
Accession (RES No)		BJ	BR	BJ	BR	BJ	BR	BJ	BR	BJ	BR	BJ	BR	Mean	SD***	Mean	SD***
PPBJ-1 Control	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	48.48	100.00	51.52	7.00	0.00	5.52	0.51
B. rapa RESR 397 Control	29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.34	0.00	89.66	100.00	6.28	0.65	6.69	0.47
B. rapa PT-303 Control	36	0.00	0.00	5.56	2.78	30.56	0.00	0.00	0.00	30.56	0.00	33.33	97.22	4.08	1.92	6.61	1.05
RESJ-919 Cutlass Original	15	26.67	60.00	73.33	40.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.46	0.40	0.51
RESJ-919 Cutlass Selfed	10	0.00	10.00	90.00	90.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.32	0.90	0.32
RESJ-998 S1 Cutlass	36	0.00	33.33	55.56	66.67	44.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.44	0.50	0.67	0.48
RESJ-1004 S1 Cutlass	38	0.00	42.11	89.47	55.26	10.53	2.63	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.31	0.61	0.55
RESJ-1005 S1 Cutlass	34	5.88	17.65	88.24	82.35	5.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.35	0.82	0.39

Table 4: Response of juvenile plants of selfed *B. juncea* var. Cutlass lines already found resistant at cotyledonary stage to isolates of *A. candida* derived from *B. juncea*[1] and *B. rapa*[2] and to inoculation with a mixture of all these isolates including 2V derived from *B. juncea*

Mixture of all isolates Accession (RES No)	Total plants	Percentage of plants expressing Interaction Phenotype*						Disease Index**	
		NN	(F)N	FN	S1	S2	S3	Mean	SD***
PPBJ-1 Control	10	0.00	0.00	0.00	0.00	0.00	100.00	7.00	0.00
B. rapa RESR-397 Control	7	0.00	0.00	0.00	14.29	71.43	14.29	4.29	1.25
B. rapa PT-303 Control	15	0.00	0.00	6.67	0.00	73.33	20.00	4.47	1.41
RESJ-919 Cutlass Original	13	7.69	0.00	0.00	7.69	15.38	69.23	5.54	2.18
RESJ-919 Cutlass Selfed	9	0.00	0.00	0.00	11.11	44.44	44.44	5.00	1.50
RESJ-998 S1 Cutlass	29	3.45	0.00	89.66	0.00	6.90	0.00	2.07	0.65
RESJ-1004 S1 Cutlass	37	2.70	0.00	16.22	2.70	45.95	32.43	4.46	1.82
RESJ-1005 S1 Cutlass	31	0.00	3.23	93.55	3.23	0.00	0.00	2.00	0.26

[1] **Isolates derived from *B. juncea***: IA05, IA06, IA09, IA10, IA11P, IA11R & 2A; [2] **Isolates derived from *B. rapa***: IA07, IA08 & IA12; *** Interaction Phenotype**: 0=NN, 1=(F)N, 2=FN, 3=S1, 4&5=S2, 6&7=S3; **** Disease Index** is mean of Interaction Phenotypes; ***** SD**=Standard Deviation

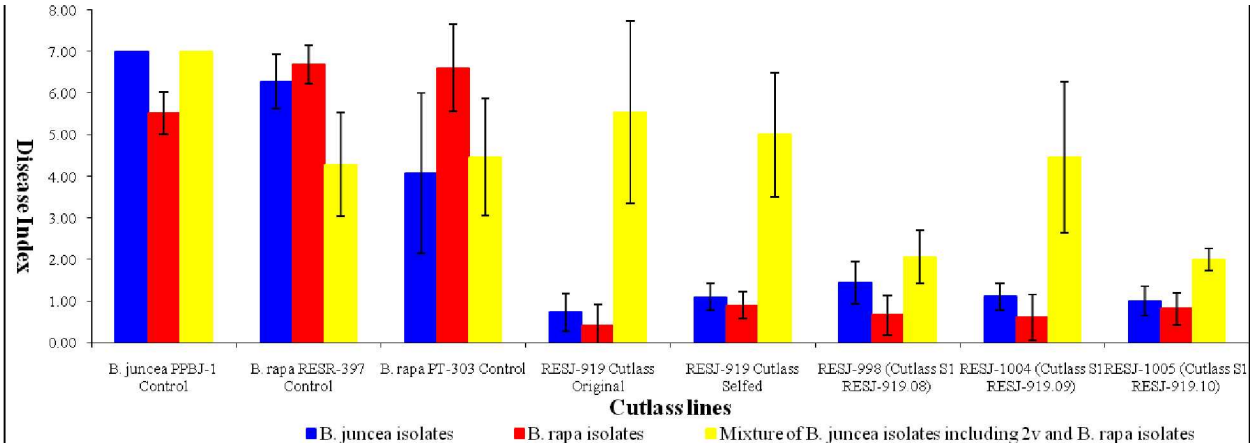

Fig 2. Disease index of S_1 *B. juncea* var. Cutlass lines in response to inoculation with *A. candida* isolate mixtures derived from *B. juncea* and *B. rapa*

Table 5: Response of juvenile plants of selfed *B. juncea* var.Cutlass lines, already found resistant to mixture of 13 isolates of *A. candida* derived from *B. juncea*[1] and *B. rapa*[2], to inoculation with isolate 2V, derived from *B. juncea*, alone

Accession (RES No)	Total plants	Number of plants expressing Interaction Phenotype*						Disease Index**	
		NN	(F)N	FN	S1	S2	S3	Mean	SD***
RESJ-998 S1 Cutlass	5	0	0	0	0	3	2	5.20	1.64
RESJ-1004 S1 Cutlass	4	0	0	1	0	1	2	5.00	2.45
RESJ-1005 S1 Cutlass	5	0	0	1	0	4	0	3.60	0.89

[1] **Isolates derived from *B. juncea*:** IA05, IA06, IA09, IA10, IA11P, IA11R, 2A & 2V; [2] **Isolates derived from *B. rapa***: IA07, IA08 & IA12.; *** Interaction Phenotype**: 0=NN, 1=(F)N, 2=FN, 3=S1, 4&5=S2, 6&7=S3; **** Disease Index** is mean of Interaction Phenotypes; ***** SD**=Standard Deviation

Table 6: Response of seedlings of selfed *B. juncea* lines to inoculation with *A. candida* isolate 2V

Accession RESJ No.	Parent	Total plants	Percentage of plants expressing Interaction Phenotype*						Disease Index**	
			NN	(F)N	FN	S1	S2	S3	Mean	SD***
965	BEC-1	23	0.00	0.00	0.00	0.00	13.04	86.96	6.43	0.95
1034	BIO-902	30	0.00	0.00	3.33	0.00	56.67	40.00	5.33	1.40
1032	CS-52	23	0.00	0.00	0.00	0.00	43.48	56.52	5.83	1.34
1033	CS-52	15	0.00	6.67	6.67	0.00	73.33	13.33	4.00	1.36
1051	CYHJ-1.1.2.1.1.1	24	33.33	0.00	4.17	8.33	50.00	4.17	2.58	1.98
1052	CYHJ-1.1.2.1.1.2	29	44.83	0.00	0.00	6.90	44.83	3.45	2.21	2.08
1042	Daulat	26	0.00	0.00	15.38	3.85	34.62	46.15	5.00	1.90
1043	Daulat	23	0.00	0.00	0.00	0.00	8.70	91.30	6.65	0.78
1049	F4BA.13.3	24	0.00	0.00	0.00	0.00	8.33	91.67	6.67	0.76
1050	F4BA.13.3	18	0.00	0.00	0.00	0.00	27.78	72.22	6.06	1.35
1047	F4BA29.4	9	0.00	0.00	0.00	0.00	55.56	44.44	5.22	1.30
1048	F4BA29.4	3	0.00	0.00	0.00	0.00	33.33	66.67	6.00	1.73
1026	Kranti	28	0.00	0.00	0.00	0.00	7.14	92.86	6.54	0.84
1027	Kranti	13	0.00	0.00	0.00	0.00	0.00	100.00	6.92	0.28
1025	Kranti	29	0.00	0.00	0.00	10.34	68.97	20.69	4.55	0.95
1053	Kranti	20	0.00	0.00	0.00	0.00	5.00	95.00	6.75	0.55
1028	Krishna	1	0.00	0.00	0.00	0.00	0.00	100.00	7.00	n/a
1055	Krishna	10	0.00	0.00	0.00	0.00	10.00	90.00	6.60	0.70
1041	PCR-7 (Rajat)	28	0.00	0.00	0.00	3.57	28.57	67.86	5.96	1.32
1057	PCR-7 (Rajat)	20	0.00	5.00	5.00	10.00	30.00	50.00	5.10	1.94
1031	PPBJ-1	27	0.00	0.00	0.00	0.00	3.70	96.30	6.63	0.56
1037	Pusa Bold	18	0.00	0.00	0.00	0.00	0.00	100.00	6.89	0.32
1038	Pusa Bold	14	0.00	0.00	0.00	0.00	0.00	100.00	6.86	0.36
1040	RES-177 (S2)	26	0.00	0.00	0.00	3.85	53.85	42.31	5.35	1.38
1056	RES-177 (S2)	25	0.00	0.00	0.00	8.00	20.00	72.00	6.00	1.32
1039	Sanjucta Asech	13	0.00	0.00	0.00	0.00	7.69	92.31	6.77	0.60
1044	Vaibhan	32	0.00	0.00	3.13	3.13	21.88	71.88	5.94	1.44
1045	Vaibhan	30	0.00	0.00	0.00	0.00	56.67	43.33	5.40	1.30
1046	Vaibhan	13	0.00	0.00	0.00	0.00	53.85	46.15	5.23	1.30
1035	Vardan	27	0.00	0.00	0.00	0.00	29.63	70.37	6.04	1.32
1036	Vardan	30	3.33	0.00	0.00	0.00	0.00	96.67	6.60	1.30
1029	Varuna	19	0.00	0.00	0.00	0.00	5.26	94.74	6.74	0.56
1030	Varuna	25	0.00	0.00	0.00	0.00	0.00	100.00	6.88	0.33
Control	PPBJ-1	89	0.00	0.00	0.00	1.12	26.97	71.91	6.10	1.15

Table 7: Response at juvenile stag of selfed *B. juncea* lines, already found resistant at cotyledon stage, to second inoculation with *A. candida* isolate 2V

Accession RESJ No.	Parent	Total plants	Number of plants expressing Interaction Phenotype*						Disease Index**	
			NN	(F)N	FN	S1	S2	S3	Mean	SD***
1034	BIO-902	1	0	0	0	0	0	1	7.00	n/a
1033	CS-52	2	0	0	0	0	1	1	5.50	2.12
1051	CYHJ-1.1.2.1.1.1	9	0	0	0	0	9	0	4.11	0.33
1052	CYHJ-1.1.2.1.1.2	13	3	0	0	0	9	1	3.31	2.06
1042	Daulat	4	0	0	0	0	3	1	5.00	1.41
1057	PCR-7 (Rajat)	2	0	0	0	0	1	1	6.00	1.41
1044	Vaibhan	1	0	0	0	0	0	1	7.00	n/a
1036	Vardan	1	0	0	0	0	0	1	7.00	n/a

growth stage, but at the true leaf stage some small pustules were observed. They were associated with necrotic areas, the pustules did not enlarge and no further infection was seen even at the mature plant and flowering stage (Fig. 1c).

Overall, these results demonstrated that almost all the important varieties of *B. juncea* being grown in India are susceptible to white rust. Accessons such as RESJ-1052, RESJ-1004, RESJ-1005, RESJ-1033 and RESJ-1051 were found to be resistant to all Indian isolates and Canadian isolate 2V. These resistant sources can be used as donors in crop improvement programme to generate putative lines that would be suitable for Indian conditions with combined resistance to Indian and Canadian isolates of *A. candida*.

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