

Evaluation of *Brassica* Germplasm for Resistance sources against White Rust

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Abstract— A series of *Brassica* germplasm NDN (National disease nursery) and UDN (Uniform disease nursery) were evaluated in field under natural epiphytotic condition followed by in glasshouse at cotyledonary and true leaf stage under controlled artificial epiphytotic condition for the confirmation of resistance against *Albugo candida* (white rust disease). In field, out of 30 (NDN) germplasm (03 no.) DRMRIJ 12-37, RH 1234 and NDRE-08-14-01 were found immune and 03, DRMRIJ 12-41, DRMRJA 35 and DRMRIJ 12-03 were found resistant. However, among UDN germplasm (34 no.), 03, DLSC-1, DRMR-312, RMM-09-04 were found immune and 02, RMWR 09-5-1, DRMR 2035, were found resistant while remaining germplasm in both the series most of them showed moderately resistant reaction and some showed moderately susceptible to susceptible reaction against white rust disease at 90 days after sowing (DAS). All these (NDN) and (UDN) germplasm were further tested in glasshouse at cotyledonary and true leaf stage for the confirmation of resistance. The (NDN) germplasm (03 no.) which were immune and 03, (total no. 6) which were moderately resistant in field at cotyledonary and true leaf stage only 02 showed immune reaction and 04 showed susceptible reaction. Similarly in (UDN), germplasm 03, showed immune reactions and 02, (total no.5) showed resistant reaction in field at cotyledonary and true leaf stage only 02 showed immune reaction and 03 showed susceptible to highly susceptible reaction. And remaining germplasm which were found moderately resistant in field in both the series most of them converted into susceptible germplasm in glasshouse. Present investigation explained that the glass house study is appropriate method for evaluation of resistance against white rust as actual resistance is obtained. However, the present findings revealed that in glasshouse (controlled artificial epiphytotic condition) at cotyledonary and true leaf stage is most important in my opinion for the confirmation rather than field study at leaf stage as some times disease escaped in field condition.

Keywords— *Albugo candida*, cotyledonary and true leaf stage, disease rating scale, phenotypic disease reaction, resistance.

I. INTRODUCTION

Albugo candida (Pers. Ex. Lev.), Kuntze is an important obligate parasite causing white rust disease in many Brassicaceae crops (Saharan and Verma, 1992). The disease cause both local and systemic infection. Local infection as white or creamy pustules on leaves and stems and systemic infection on meristems and inflorescence gives rise to malformed racemes called "stag head". The disease causes annual yield loss in Mustard about 20-60 percent (Saharan *et al.*, 1984 and Kolte, 2002). Saharan, (1992) reported 23-35 percent yield loss and Bisht *et al.* (1994) reported 17-34 percent yield loss due to the mixed infection of white and downy mildew in rapeseed-mustard. Protectants fungicides have been recommended to controlling this disease of mustard Kolte and Tewari, (1978) and Kolte and Awasthi, (1980). But due to their environmental hazards, unavailability in global market and high cost, farmers are unable to use these fungicides. The alternative method, such as identification and cultivation of resistant cultivars is considered as eco- friendly, cost effective disease management strategy. Availability of resistant source has been reported by the several workers and different criteria have been used by the workers to determine the relative resistance of various genotypes in oilseed brassica Ashrufuzzaman, *et al.*, (1996); Kumar and Kolte, (2001). However, less work has been done to understanding the various aspect of disease component in resistant and susceptible genotypes. In this view, to develop resistant cultivars in Mustard against this disease, it is very important to identify and confirm the resistant sources. So, that some promising and potential genotypes would be identified and used as donor in the resistant breeding programme. The main focus for identification of resistant sources field level testing. It is appropriate method but needs confirmation as some times disease is escaped due to low disease pressure

as well as due to some other reasons. Considering the problems, the present investigation was undertaken for the confirmation of resistant sources in *Brassica* germplasm against *A. candida*.

II. MATERIALS AND METHODS

The *Brassica* germplasm NDN (National Disease Nursery) (30 no.), and UDN (Uniform Disease Nursery) (34 no.),

NBPGR, New Delhi, were used for the identification of resistance sources against white rust. The study was conducted in field under natural epiphytotic condition during the crop season 2014-2015 and all these germplasm were further tested in glasshouse under controlled artificial epiphytotic condition for the confirmation during the crop season 2015-2016.

Table.1: 64 (NDN and UDN) *Brassica* germplasm

SI.No.	NDN (National Disease Nursery)		Brassica species	UDN (Uniform Disease Nursery)		Brassica species
1.	NDN-15-33	Bioysr	<i>Brassica juncea</i>	UDN-15-1	Rohini	<i>Brassica juncea</i>
2.	NDN-15-34	Rohini	<i>Brassica juncea</i>	UDN-15-2	PHR-2	<i>Brassica juncea</i>
3.	NDN-15-35	DRMRIJ 12-51	<i>Brassica juncea</i>	UDN-15-3	DLSC-1	<i>Brassica juncea</i>
4.	NDN-15-36	DRMRIJ 12-02	<i>Brassica juncea</i>	UDN-15-4	EC 399299	<i>Brassica juncea</i>
5.	NDN-15-37	DRMRIJ 12-27	<i>Brassica juncea</i>	UDN-15-5	RMM 09-01-1	<i>Brassica juncea</i>
6.	NDN-15-38	RH 1231	<i>Brassica juncea</i>	UDN-15-6	DRMR 32	<i>Brassica carinata</i>
7.	NDN-15-39	DRMRIJ 12-41	<i>Brassica juncea</i>	UDN-15-7	PRD 2014-21	<i>Brassica juncea</i>
8.	NDN-15-40	DRMRIJ 12-14	<i>Brassica juncea</i>	UDN-15-8	PRD 2013-3	<i>Brassica juncea</i>
9.	NDN-15-41	DRMRIJ 12-39	<i>Brassica juncea</i>	UDN-15-9	RMWR 09-5-1	<i>Brassica juncea</i>
10.	NDN-15-42	DRMR-2035	<i>Brassica juncea</i>	UDN-15-10	DRMRJA 35	<i>Brassica juncea</i>
11.	NDN-15-43	DRMRIJ 12-48	<i>Brassica juncea</i>	UDN-15-11	DRMR 2035	<i>Brassica juncea</i>
12.	NDN-15-44	DRMRIJ 12-06	<i>Brassica juncea</i>	UDN-15-12	ABS(3)-21	<i>Brassica juncea</i>
13.	NDN-15-45	RMWR-09-05-01	<i>Brassica juncea</i>	UDN-15-13	DRMR-73	<i>Brassica carinata</i>
14.	NDN-15-46	DRMRJA 35	<i>Brassica juncea</i>	UDN-15-14	RMM 10-1-1	<i>Brassica juncea</i>
15.	NDN-15-47	DRMRIJ 12-44	<i>Brassica juncea</i>	UDN-15-15	PRD 2013-8	<i>Brassica juncea</i>
16.	NDN-15-48	DRMRIJ 12-03	<i>Brassica juncea</i>	UDN-15-16	DRMR-2019	<i>Brassica juncea</i>
17.	NDN-15-49	RH 305	<i>Brassica juncea</i>	UDN-15-17	DRMR-72	<i>Brassica carinata</i>
18.	NDN-15-50	DRMRIJ 12-21	<i>Brassica juncea</i>	UDN-15-18	ABS(3)-16	<i>Brassica carinata</i>
19.	NDN-15-51	DRMRIJ 12-37	<i>Brassica juncea</i>	UDN-15-19	DRMR-312	<i>Brassica carinata</i>
20.	NDN-15-52	NPJ 181	<i>Brassica juncea</i>	UDN-15-20	NPJ-177	<i>Brassica juncea</i>
21.	NDN-15-53	DRMRIJ 12-26	<i>Brassica juncea</i>	UDN-15-21	PRD 2013-6	<i>Brassica juncea</i>
22.	NDN-15-54	RMWR-09-05	<i>Brassica juncea</i>	UDN-15-22	NPJ-177	<i>Brassica juncea</i>
23.	NDN-15-55	DRMR-2019	<i>Brassica juncea</i>	UDN-15-23	PRD 2013-9	<i>Brassica juncea</i>
24.	NDN-15-56	DRMRIJ 12-50	<i>Brassica juncea</i>	UDN-15-24	PRD 2013-2	<i>Brassica juncea</i>
25.	NDN-15-57	RH 1234	<i>Brassica juncea</i>	UDN-15-25	DRMR 100	<i>Brassica carinata</i>
26.	NDN-15-58	DRMRIJ 12-28	<i>Brassica juncea</i>	UDN-15-26	ABS(3)-44	<i>Brassica juncea</i>
27.	NDN-15-59	NDRE-08-14-01	<i>Brassica juncea</i>	UDN-15-27	DRMR-40	<i>Brassica carinata</i>
28.	NDN-15-60	DRMRIJ 12-65	<i>Brassica juncea</i>	UDN-15-28	ABS(3)-15	<i>Brassica carinata</i>
29.	NDN-15-61	DRMRIJ 12-43	<i>Brassica juncea</i>	UDN-15-29	RMM 09-1-1-2	<i>Brassica juncea</i>
30.	NDN-15-62	DRMRIJ 12-40	<i>Brassica juncea</i>	UDN-15-30	RMM-09-04	<i>Brassica juncea</i>
31.				UDN-15-31	DRMR-316	<i>Brassica carinata</i>
32.				UDN-15-32	PRE-2011-15	<i>Brassica juncea</i>
33.				UDN-15-33	RH-1212	<i>Brassica juncea</i>
34.				UDN-15-34	DRMR-7	<i>Brassica carinata</i>

Screening under natural epiphytotic conditions

The *Brassica* germplasm were sown on Oct.15, 2014 in a Randomized Block Design. Two row of 3m length of each line were sown with (5-10 cm) plant to plant distance. A susceptible check (Varuna) was sown after each two rows.

Plants were thinned out after 15 days of germination. Two irrigations were applied. Ten plants were randomly selected in each row of each germplasm and tagged to record observations. The observations on disease severity of white rust disease was recorded 90 days after sowing (DAS) at

maximum disease pressure using 0-9 disease rating scale (Conn *et al.*, 1990).

Screening under glasshouse conditions

Raising of seedlings

Each *Brassica* germplasm sown in (10-cm-dia.) plastic pots were placed in a plastic tray. The trays along with pots were then kept in the glasshouse. In each pot, ten seedlings were maintained. Two sets of each germplasm replicated by two times were prepared for the inoculation. One set for inoculation of zoospore suspension at cotyledonary stage (7 DAS) and other for at true leaf stage (15 DAS).

Inoculum preparation and inoculation

Pantnagar isolate (highly virulent) was taken for the study. The isolate was first multiplied on susceptible cultivar i.e. Varuna. Sporangial suspension from single pustule of *A. candida* collected from freshly infected leaves of Varuna was prepared in sterilized doubled distilled water. The sporangial suspension was then incubated at 10°C for 8 hrs for the release of zoospores. The sporangial concentration (2.5×10^5 sporangia/ml) was adjusted using haemocytometer. Each plants of different *Brassica* germplasm were inoculated with the zoospore suspension at cotyledonary (7 DAS) and at true leaf stage (15 DAS). The inoculation was done during the month of Dec-Jan. (2015-16). Inoculated plants were kept in plant propagator in glasshouse at $18 \pm 2^\circ\text{C}$ to maintain 80-90 percent RH for 72 hrs. The pots were then removed from the plant propagator and kept in glasshouse at $18 \pm 2^\circ\text{C}$. Proper RH was maintained by humidifier during growth period for the development of symptoms at cotyledonary and true leaf stage.

Disease assessment

The observations on disease index and phenotypic disease reaction at cotyledonary and true leaf

Stage were recorded at 15 days after each inoculation (DAI) using 0-6 rating scale (Conn *et al.*, 1990 and 0-7 rating scale (Leekie *et al.*, 1996) respectively.

The Percent Disease index was calculated by using the following formula:

$$\text{Disease index (\%)} = \frac{\text{Sum of all numerical ratings}}{\text{Number of leaves examined} \times \text{Maximum grade}} \times 100$$

III. RESULT AND DISCUSSIONS

Disease reactions and disease severity of *Brassica* germplasm (NDN & UDN) against white rust in field under natural epiphytotic conditions

In field, (NDN) germplasm, 03, DRMRIJ 12-37, RH 1234, NDRE-08-14-01 were found immune (0 %) ; 03, DRMRIJ

12-41, DRMRJA 35, DRMRIJ 12-03, were found resistant (5.56-8.34 %); 13, Rohini, DRMRIJ 12-27, RH 1231, DRMRIJ 12-14, DRMRIJ 12-39, DRMR-2035, DRMRIJ 12-48, DRMRIJ 12-06, DRMRIJ 12-44, RH 305, RMWR-09-05, DRMR-2019, DRMRIJ 12-65 were found moderately resistant (11.11-25%) while 09, Bioysr, DRMRIJ 12-51, DRMRIJ 12-02, RMWR-09-05-01, DRMRIJ 12-21, DRMRIJ 12-26, DRMRIJ 12-28, DRMRIJ 12-43, DRMRIJ 12-40 were found susceptible (30.56-47.22 %). (UDN) germplasm, 03, DLSC-1, DRMR-312, RMM-09-04 were found immune (0 %) ; 02, RMWR 09-5-1 and DRMR 2035, were found resistant (5.56-8.34 %); 06, PHR-2, EC 399299, RMM 09-01-1, ABS(3)-21, DRMR-2019, DRMR-72 were found moderately resistant (11.11-22.22 %) ; 15, Rohini, DRMR 32, PRD 2014-21, PRD 2013-3, DRMR-73, RMM 10-1-1, PRD 2013-8, ABS (3) -16, NPJ-177, DRMR-100, PRD 2013-2, ABS (3) - 44, DRMR-40, RMM 09-1-1-2, DRMR-316, DRMR-7 were found susceptible (27.78-44.44%) while, 05, RH-1212, PRD 2013-15, ABS (3)-15, PRD 2013-9 and PRD 2013-6 were found highly susceptible (55.55-63.89 %) against white rust disease (**Table 2**). In the present study, field evaluation, 03 germplasm DRMRIJ 12-37, RH 1234, NDRE-08-14-01 (NDN) series and 03 DLSC-1, DRMR-312, RMM-09-04 (UDN) showed immune reaction, while in glasshouse at cotyledonary leaf and true leaf stage 02 (NDN) (RH 1234, NDRE-08-14-01) and 02 (UDN) (DLSC-1, DRMR-312) showed immune reaction and 01 (NDN) DRMRIJ 12-37 and 01 (UDN) RMM-09-04 had converted into susceptible germplasm. Similarly germplasm which were found resistant and moderately resistant in field condition most of them converted into susceptible to highly susceptible germplasm in glasshouse (High disease pressure and controlled artificial epiphytotic condition) (**Table 7**). Resistance is more appropriate and authentic when recorded with artificial inoculation. The present findings revealed that glasshouse evaluation at cotyledonary and at true leaf stage is essential for the confirmation of resistant sources in *Brassicas* against *A. candida* (white rust disease). However, field testing was a routine method for the evaluation of resistant sources by earlier workers in which sometimes disease is escaped and showed immune/resistant reactions. Bisht *et al.* (2016) evaluated 240 *Brassica* materials in field and among them 03 were found immune. DRMR (2011) reported EC 399313 as a resistant source against white rust only through field studies. Pandey *et al.*, (2013) found that GSL-1, PBC-9221, NDCDR-515 were highly resistant to white rust. Meena *et al.*, (2011) also found that PBC 9221, and EC 414299 *Brassica* species were resistant in field

against white rust. However, in the present study it is described that glasshouse study at cotyledonary and true leaf stage is essential after field evaluation.

Disease reactions and Percent disease index of *Brassica* germplasm (NDN & UDN) against white rust in glasshouse under controlled epiphytotic conditions

The sporangial size and shape of *A. candida* (Pantnagar isolate) used in the present investigation was 20.21 µm and globular type. This finding is similar with the work of Kolte (1985) and Patni *et al.*, (2005) also reported that the shape of sporangia of different *A. candida* isolates varied from slightly spherical to globular type and size in different isolates ranged from 12-18 µm, 13.55-21.78 µm and 13.5-20.9 µm. Pustules size was ranged between 0.5-1.0 mm (small), 3-5 mm (Large) and 1-3 mm (Medium) at cotyledonary and true leaf stage. These findings are within the range of earlier reported values of Mishra *et al.*, (2009). The incubation period (IP) was varied from 4.33-8.67 days and latent period (LP) from 5.33-10.67 days at cotyledonary stage. Whereas, at true leaf stage, the incubation period was ranged between 10.67-17.67 days and latent period (LP) varied between 11.67-19.67 days. Similar results were also noticed by Mishra *et al.*, (2009) (Table 3).

Phenotypic disease reactions

NDN germplasm

At cotyledon leaf stage, the NDN entries viz. RH 1234 and NDRE-08-14-01 were showed disease reaction immune type (NN) kept in **Group I**; the entries viz. NPJ 181, RH 305, DRMRIJ 12-40 and Rohini showed disease reaction S3-6 type (large scattered pustules) on lower surface were kept **Group II**; the entries viz. DRMRIJ 12-14, Bioysr and DRMRIJ 12-21 which showed show disease S3-7 type (large coalescing pustules) on lower surface reaction were kept in **Group III**; the entries viz. DRMRIJ 12-43, DRMR 12-39, DRMR-2035, DRMRIJ 12-65, DRMRIJ 12-28, DRMRIJ 12-37, DRMRIJ 12-03, DRMRJA 35, RMWR-09-05-01, RH 1231, DRMR 12-28, DRMRIJ 12-50 and DRMRIJ 12-51 showed disease reaction S2-5 type (numerous pustules) on lower surface were kept in **Group IV**; the entries viz. DRMR-2019, DRMRIJ 12-26, DRMRIJ 12-06, DRMRIJ 12-41, DRMRIJ 12-48, DRMRIJ 12-44, DRMRIJ 12-27, RM-09-05 and DRMRIJ 12-02 showed disease reaction S2-4 type (few pustules) on lower leaf surface were kept in **Group V**. At true leaf stage, the NDN entries viz. RH 1234 and NDRE-08-14-01 were showed disease reaction immune type (NN) kept in **Group I**; the entries viz. Bioysr, DRMRIJ 12-27, DRMJJA 35, RMWR-09-05-01, DRMRIJ 12-03, RH 305, DRMRIJ 12-

21, DRMRIJ 12-37, DRMRIJ 12-26, DRMRIJ 12-43 and DRMRIJ 12-40 showed disease reaction S3-6 type (large scattered pustules) on lower surface were kept **Group II**; the entries viz. DRMRIJ 12-50, DRMRIJ 12-28, DRMRIJ 12-48, DRMR-2035, DRMRIJ 12-39, DRMRIJ 12-14, RH 1231, DRMRIJ 12-02, DRMRIJ 12-02, DRMRIJ 12-51, Rohini showed disease reaction S2-5 type (numerous pustules) on lower surface were kept in **Group IV**; the entries viz. DRMRIJ 12-06, DRMRIJ 12-44, NPJ 181, RMWR-09-05, DRMR-2019, DRMRIJ 12-65 showed disease reaction S2-4 type (few pustules) on lower leaf surface were kept in **Group V** (Table 4).

Percent disease index:

At cotyledonary leaf stage, significantly maximum PDI was observed in DRMRIJ-12-41 (52.56%) and minimum PDI was observed in DRMRIJ 12-51 (12.11%) and PDI in remaining germplasm showed in the range of (21.01-50.56 %). At true leaf stage, significantly maximum PDI was observed in RH 305 (47.68%) and minimum PDI was observed in DRMRIJ 2019 (14.56%). PDI in remaining germplasm showed in the range of (16.01-45.01 %) (Table 6).

UDN germplasm

At cotyledon leaf stage, the UDN entries viz. DLSC-1 and DRMR-312 were showed disease reaction immune type (NN) kept in **Group I**; the entries viz. Rohini, EC 399299, PRD 2014-21, RMM-09-04 and DRMR-316 showed disease reaction S3-6 type (large scattered pustules) on lower surface were kept **Group II**; the entries viz. DRMR 32 which showed show disease S3-7 type (large coalescing pustules) on lower surface reaction were kept in **Group III**; the entries viz. PHR-2, RMM 09-01-1, PRD 2013-3, RMWR 09-5-1, RMM 10-1-1, PRD 2013-8, DRMR-2019, PRD 2013-6, PRD 2013-9, PRD 2013-2, DRMR 100, ABS (3)-44, DRMR-40, PRE-2011-15, RH-1212, and DRMR-7 232 showed disease reaction S2-5 type (numerous pustules) on lower surface were kept in **Group IV**; the entries viz. DRMRMJ 35, DRMR 2035, ABS (3)-21, DRMR-73, DRMR-72, ABS (3)-16, NPJ-177, ABS (3)-15, and RMM 09-1-1-2 showed disease reaction S2-4 type (few pustules) on lower leaf surface were kept in **Group V**. At true leaf stage, the UDN entries viz. DLSC-1 and DRMR-312 were showed disease reaction immune type (NN) kept in **Group I**; the entries viz. PHR-2, EC 399299, ABS (3)-15, DRMR-2019, RMM 10-1-1, DRMR-73, ABS(3)-21, PRD 2013-3, PRD 2014-21 and DRMR 32 showed disease reaction S3-6 type (large scattered pustules) on lower surface were kept **Group II**; the entries viz. DRMR-72 and PRD 2013-8 which showed show disease S3-7 type (large coalescing

pustules) on lower surface reaction were kept in **Group III**; the entries **viz.** Rohini, RMM 09-01-1, ABS(3)-16, NPJ-177, RH-1212, DRMR-316, RMM-09-04, RMM 09-1-1-2, DRMR-40, DRMR 100, PRD 2013-9, NPJ-177, PRD 2013-6, PRE-2011-15, DRMR-7, ABS(3)-44 showed disease reaction S2-5 type (numerous pustules) on lower surface were kept in **Group IV**; the entries **viz.** PRD 2013-2, DRMR 2035 and RMWR 09-5-1 showed disease reaction S2-4 type (few pustules) were kept in **Group V (Table 5).**

Percent disease index:

At cotyledonary leaf stage, significantly maximum PDI was observed in DRMR-32 (50.51%) and minimum PDI was observed in NPJ (11.56%). PDI in remaining germplasm showed in the range of (12.11-45.28 %). At true leaf stage, significantly maximum PDI was in RH 305 (55.01%) and minimum PDI was observed in DRMRIJ 12-48 (18.01%). PDI in remaining germplasm showed in the range of (19.21-54.01 %) (**Table 6**).

Comparison of disease reactions in field and in glasshouse

In field the germplasm which showed immune, resistant and moderately resistant reactions most of them were found susceptible, moderately susceptible and highly susceptible under glasshouse study at cotyledonary and at true leaf stage. The findings revealed that the germplasm must be tested at cotyledonary and true leaf stage rather than field study in glasshouse for the confirmation of resistant sources (**Table 7**).

IV. CONCLUSION

The present investigation on evaluation for resistant sources in *Brassica* germplasm (NDN and UDN) against *A. candida* revealed that, the field evaluation is not a desirable technique to find out the resistant resources as sometimes disease escaped and showed resistant reactions. Therefore, the present investigation conclusively demonstrated that resistance must be confirmed in glasshouse under controlled artificial inoculation conditions at cotyledonary and true leaf stages both followed by field testing. The glasshouse testing would be helpful in confirming the resistance in *Brassicacae* against *A. candida* (white rust) within a shorter period of time i.e. with 25 days after sowing.

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Table.2: Percent disease severity and disease reactions of different *Brassica* germplasm under NDN and UDN against *A. candida* in field (2015-16)

S.No.	NDN	DS		DR	UDN	DS		DR
1.	Bioysr	41.67	(40.18)	S	Rohini	33.33	(35.26)	S
2.	Rohini	13.89	(21.78)	MR	PHR-2	11.11	(19.47)	MR
3.	DRMRIJ 12-51	36.11	(36.91)	S	DLSC-1	ND	ND	ND
4.	DRMRIJ 12-02	36.11	(36.11)	S	EC 399299	11.11	(19.47)	MR
5.	DRMRIJ 12-27	13.89	(21.78)	MR	RMM 09-01-1	22.22	(28.12)	MR
6.	RH 1231	22.22	(28.11)	MR	DRMR 32	30.56	(33.53)	S
7.	DRMRIJ 12-41	5.56	(13.63)	R	PRD 2014-21	36.11	(36.92)	S
8.	DRMRIJ 12-14	13.89	(21.78)	MR	PRD 2013-3	41.67	(40.19)	S
9.	DRMRIJ 12-39	11.11	(19.46)	MR	RMWR 09-5-1	8.34	(16.55)	R
10.	DRMR-2035	19.45	(26.10)	MR	DRMRJA 35	11.11	(19.47)	MR
11.	DRMRIJ 12-48	11.11	(19.46)	MR	DRMR 2035	5.56	(13.64)	R
12.	DRMRIJ 12-06	11.11	(19.46)	MR	ABS(3)-21	13.89	(21.78)	MR
13.	RMWR-09-05-01	47.22	(43.39)	S	DRMR-73	30.56	(33.53)	S
14.	DRMRJA 35	5.56	(13.63)	R	RMM 10-1-1	47.22	(43.40)	S
15.	DRMRIJ 12-44	13.34	(21.26)	MR	PRD 2013-8	27.78	(31.81)	S
16.	DRMRIJ 12-03	8.34	(16.55)	R	DRMR-2019	13.89	(21.78)	MR
17.	RH 305	11.11	(19.46)	MR	DRMR-72	22.22	(28.12)	MR
18.	DRMRIJ 12-21	47.22	(43.39)	S	ABS(3)-16	38.89	(38.58)	S
19.	DRMRIJ 12-37	ND	ND	ND	DRMR-312	ND	ND	ND
20.	NPJ 181	NG	NG	NG	NPJ-177	22.22	(28.12)	MR
21.	DRMRIJ 12-26	36.11	(36.91)	S	PRD 2013-6	55.55	(48.19)	HS
22.	RMWR-09-05	13.89	(21.78)	MR	NPJ-177	33.33	(35.26)	S

23.	DRMR-2019	11.11	(19.46)	MR	PRD 2013-9	58.33	(49.80)	HS
24.	DRMRIJ 12-50	NG	NG	NG	PRD 2013-2	44.44	(41.81)	S
25.	RH 1234	ND	ND	ND	DRMR 100	47.22	(43.40)	S
26.	DRMRIJ 12-28	30.56	(33.52)	S	ABS(3)-44	38.89	(38.58)	S
27.	NDRE-08-14-01	ND	ND	ND	DRMR-40	33.33	(35.26)	S
28.	DRMRIJ 12-65	25.00	(29.95)	MR	ABS(3)-15	55.55	(48.19)	HS
29.	DRMRIJ 12-43	41.67	(40.18)	S	RMM 09-1-1-2	43.05	(41.00)	S
30.	DRMRIJ 12-40	30.56	(33.52)	S	RMM-09-04	ND	ND	ND
31.					DRMR-316	47.22	(43.40)	S
32.					PRE-2011-15	58.33	(49.80)	HS
33.					RH-1212	63.89	(53.08)	HS
34.					DRMR-7	41.90	(39.89)	S
	C.D. 5%	(4.38)				(3.48)		
	CV	(8.64)				(5.54)		

DS=Disease severity; DR=Disease reaction; ND=No disease; NG=Not germinated

*Values in parenthesis are angular transformed

Table.3: Effect of different Brassica germplasm (NDN) on Incubation period, Latent period, Pustules size and Pattern of *A. candida* in glasshouse (2015-2016)

Germplasm	Cotyledonary stage				True leaf			
	Incubation period	Latent Period	Pustules size (mm)	Pustules pattern	Incubation Period	Latent Period	Pustules size (mm)	Pustules pattern
Bioysr	5.00	5.67	0.5-1,1- 3	S,R,C	11.00	12.00	0.5-1,1-3	S,R,C
Rohini	5.67	8.67	0.5-1,1-3	S,R,C	11.67	12.67	0.5-1,1-3	S,R,C
DRMRIJ 12-51	5.67	7.00	0.5-1	S,R,	15.67	17.67	3-5	S,C
DRMRIJ 12-02	6.00	8.00	0.5-1	S,R	14.67	16.67	3-5	S,C
DRMRIJ 12-27	4.67	7.00	0.5-1	S,R	10.67	13.67	0.5-1	S,R
RH 1231	5.67	8.00	0.5-1	S,R	10.67	11.67	0.5-1,1-3	S,R,C
DRMRIJ 12-41	4.67	8.33	0.5-1	S,R	12.67	13.67	0.5-1	R,S
DRMRIJ 12-14	6.00	7.00	0.5-1,1-3	S,R,C	16.67	18.67	0.5-1, 3-5	S,R,C
DRMRIJ 12-39	6.67	8.33	0.5-1	S,R	11.67	14.67	0.5-1	R,S
DRMR-2035	6.00	7.67	0.5-1,1-3	S,R,C	16.67	18.67	3-5	S,R,C
DRMRIJ 12-48	5.67	8.00	0.5-1,1-3	S,R,C	15.67	17.67	0.5-1	S,R
DRMRIJ 12-06	4.00	6.67	0.5-1,1-3	S,R,C	17.67	20.67	0.5-1	S,R
RMWR-09-05-01	5.67	7.67	0.5-1	S,R	12.67	14.67	0.5-1,1-3	S,R,C
DRMRJA 35	4.00	5.67	0.5-1	S,R	11.67	12.67	0.5-1	R,S
DRMRIJ 12-44	6.67	7.67	0.5-1,1-3	S,R,C	10.67	11.67	0.5-1,1-3	S,R,C
DRMRIJ 12-03	4.00	5.33	0.5-1	S,R	10.67	12.67	0.5-1	R,S
RH 305	4.67	6.67	0.5-1	S,R	16.67	18.67	0.5-1	S,R
DRMRIJ 12-21	7.00	8.33	1-3	S,R	15.67	18.67	0.5-1, 3-5	S,R,C
DRMRIJ 12-37	4.33	6.00	0.5-1,1-3	S,R,C	12.67	14.67	0.5-1	S,R
NPJ 181	7.00	8.67	0.5-1	S,R	16.67	19.67	0.5-1	S,R
DRMRIJ 12-26	5.67	7.67	0.5-1	S,R	14.67	17.67	0.5-1	S,R
RMWR-09-05	5.00	6.33	0.5-1,1-3	S,R,C	14.00	15.67	0.5-1	S,R
DRMR-2019	4.33	6.33	0.5-1	S,R	15.67	15.00	0.5-1	S,R
DRMRIJ 12-50	5.67	7.33	0.5-1	S,R	17.67	20.33	0.5-1	S,R
RH 1234	0.00	0.00	0	0	0.00	0.00	0	0

DRMRIJ 12-28	6.67	8.00	0.5-1,1-3	S,R,C	13.00	15.33	0.5-1, 1-3	S,R,C
NDRE-08-14-01	0.00	0.00	0	0	0.00	0.00	0	0
DRMRIJ 12-65	5.67	8.00	0.5-1	S,R	16.67	18.67	0.5-1	S,R
DRMRIJ 12-43	7.67	9.33	0.5-1,1-3	S,R,C	15.67	17.67	0.5-1	S,R
DRMRIJ 12-40	8.67	10.67	0.5-1,1-3	S,R,C	14.00	15.67	0.5-1	S,R
CD 5%	0.73	0.80	-	-	1.19	0.87	-	-
CV	8.47	7.06	-	-	5.56	3.60	-	-

NDN=National disease nursery; S=Scattered, C=Circular, R=Raised

Table.4: Effect of different Brassica germplasm (UDN) on Incubation period, Latent period, Pustules size and Pattern of *A. candida* in glasshouse (2015-2016)

Germplasm	Cotyledonary stage				True leaf			
	Incubation Period	Latent Period	Pustules size (mm)	Pustules pattern	Incubation Period	Latent Period	Pustules size (mm)	Pustules pattern
Rohini	5.00	6.00	0.5-1	S,R	8.00	11.00	0.5-1	R,S
PHR-2	4.67	6.67	0.5-1,1-3	S,R,C	9.67	10.67	0.5-1	R,S
DLSC-1	0.00	0.00	0	0	0.00	0.00	0	0
EC 399299	4.67	6.00	0.5-1	S,R	10.67	13.33	0.5-1	R,S
RMM 09-01-1	5.67	7.67	1-3	R,C	12.67	15.00	0.5-1	R,S
DRMR 32	4.67	6.00	0.5-1,1-3	S,R,C	14.67	15.67	0.5-1,1-3	R,S
PRD 2014-21	6.33	6.67	0.5-1	S,R	12.67	14.00	0.5-1	R,S
PRD 2013-3	4.67	6.00	0.5-1	S,R	15.67	17.67	0.5-1	R,S
RMWR 09-5-1	6.67	7.67	0.5-1	S,R	11.67	16.00	0.5-1,1-3	R,S
DRMRMJA 35	4.67	6.00	0.5-1	S,R	15.00	16.67	0.5-1	R,S
DRMR 2035	4.33	5.67	0.5-1	S,R	10.67	14.00	0.5-1	R,S
ABS(3)-21	8.33	9.00	0.5-1	S,R,C	11.67	12.67	0.5-1	R,S
DRMR-73	5.67	6.67	0.5-1	S,R	14.67	16.00	0.5-1,1-3	R,S
RMM 10-1-1	6.67	7.67	0.5-1	S,R	12.67	14.67	0.5-1	R,S
PRD 2013-8	4.67	7.00	0.5-1	S,R	10.67	12.00	0.5-1	R,S
DRMR-2019	5.33	5.67	0.5-1	S,R	13.67	15.67	0.5-1,1-3	R,S
DRMR-72	6.33	7.67	0.5-1	S,R	12.67	16.00	0.5-1	R,S
ABS(3)-16	4.67	6.00	0.5-1	S,R	15.00	16.67	0.5-1	R,S
DRMR-312	0.00	0.00	0	0	0.00	0.00	0	0
NPJ-177	6.33	7.67	0.5-1	S,R	14.67	15.67	0.5-1	R,S
PRD 2013-6	6.67	7.67	0.5-1	S,R	8.00	10.67	0.5-1,1-3	S,R,C
NPJ-177	4.67	6.00	0.5-1	S,R	9.67	12.00	0.5-1	R,S
PRD 2013-9	4.33	6.67	0.5-1	S,R	11.00	11.67	0.5-1,1-3	R,S
PRD 2013-2	6.33	7.00	0.5-1	S,R	11.33	14.00	0.5-1,1-3	R,S
DRMR 100	4.33	5.67	0.5-1	S,R	12.00	13.67	0.5-1	R,S
ABS(3)-44	6.33	7.00	0.5-1	S,R	10.67	13.00	0.5-1,1-3	R,S
DRMR-40	4.67	5.67	0.5-1	S,R	13.00	15.67	0.5-1	R,S
ABS(3)-15	6.67	8.00	0.5-1	S,R	11.67	14.00	0.5-1	R,S
RMM 09-1-1-2	5.67	7.67	0.5-1	S,R	13.00	13.67	0.5-1	R,S
RMM-09-04	5.67	8.00	0.5-1	S,R	13.67	16.00	0.5-1,1-3	R,S
DRMR-316	6.67	7.67	0.5-1	S,R	11.00	12.67	0.5-1	R,S
PRE-2011-15	5.67	7.00	0.5-1	S,R	12.33	15.00	0.5-1,1-3	R,S
RH-1212	7.67	8.67	0.5-1	S,R	14.00	15.67	0.5-1	R,S

DRMR-7	4.67	6.67	0.5-1	S,R	11.67	14.00	0.5-1	R,S
CD 5%	0.94	0.73	-	-	0.75	0.66	-	-
CV	10.94	6.98	-	-	4.48	3.05	-	-

UDN=Uniform disease nursery; S=Scattered, C=Circular, R=Raised

Table.5: Phenotypic disease reactions of different Brassica germplasm under NDN and UDN against *A. candida* in glasshouse (2015-16)

NDN	Cotyledonary leaf stage	DR	True leaf stage	DR
	RH 1234 and NDRE-08-14-01 (02)	NN	RH 1234 and NDRE-08-14-01 (02)	NN
	NPJ 181, RH 305,DRMRIJ 12-40 and Rohini (04)	S3-6	Bioysr, DRMRIJ 12-27, DRMJJA 35,RMWR-09-05-01, DRMRIJ 12-03, RH 305, DRMRIJ 12-21,DRMRIJ 12-37,DRMRIJ 12-26, DRMRIJ 12-43 and DRMRIJ 12-40 (11)	S3-6
	DRMRIJ 12-14,Bioysr and DRMRIJ 12-21 (03)	S3-7	DRMRIJ 12-50, DRMRIJ 12-28, DRMRIJ 12-48, DRMR-2035, DRMRIJ 12-39, DRMRIJ 12-14, RH 1231, DRMRIJ 12-02, DRMRIJ 12-02, DRMRIJ 12-51, Rohini (11)	S2-5
	DRMRIJ 12-43,DRMR 12-39,DRMR-2035, DRMRIJ 12-65, DRMRIJ 12-28, DRMRIJ 12-37, DRMRIJ 12-03, DRMRJA 35, RMWR-09-05-01, RH 1231,DRMR 12-28,DRMRIJ 12-50 and DRMRIJ 12-51 (13)	S2-5	DRMRIJ 12-06, DRMRIJ 12-44,NPJ 181, RMWR-09-05,DRMR-2019,DRMRIJ 12-65 (06)	S2-4
	DRMR-2019, DRMRIJ 12-26, DRMRIJ 12-06, DRMRIJ 12-41, DRMRIJ 12-48, DRMRIJ 12-44, DRMRIJ 12-27,RM-09-05 and DRMRIJ 12-02 (09)	S2-4		
UDN	Cotyledonary leaf stage		True leaf stage	
	DLSC-1 and DRMR-312 (02)	NN	DLSC-1 and DRMR-312 (02)	NN
	Rohini, EC 399299, PRD 2014-21, RMM-09-04 and DRMR-316 (05)	S3-6	PHR-2, EC 399299, ABS (3)-15, DRMR-2019, RMM 10-1-1, DRMR-73, ABS(3)-21, PRD 2013-3, PRD 2014-21 and DRMR 32 (10)	S3-6
	DRMR 32 (01)	S3-7	DRMR-72 and PRD 2013-8 (02)	S3-7
	PHR-2, RMM 09-01-1, PRD 2013-3, RMWR 09-5-1, RMM 10-1-1, PRD 2013-8, DRMR-2019, PRD 2013-6, PRD 2013-9, PRD 2013-2, DRMR 100, ABS (3)-44, DRMR-40, PRE-2011-15, RH-1212, and DRMR-7 232 (16)	S2-5	Rohini, RMM 09-01-1, DRMR-7, RH-1212, DRMR-316, RMM-09-04, RMM 09-1-1-2, DRMR-40, ABS(3)-44, DRMR 100, PRD 2013-9, NPJ-177, PRD 2013-6, ABS(3)-16, and DRMRMJA 35. (15)	S2-5
	DRMRMJ 35, DRMR 2035, ABS (3)-21, DRMR-73, DRMR-72, ABS (3)-16, NPJ-177, ABS (3)-15, and RMM 09-1-1-2 (09)	S2-4	PRD 2013-2, DRMR 2035 and RMWR 09-5-1 (03)	S2-4

DR=Disease reactions; NN= No sporulation (0); S2-4= Few pustules on lower leaf surface (4); S2-5= Numerous Pustules on lower leaf surface (5); S3-6= Large scattered pustules on lower leaf surface (6)

Table.6: Percent Disease index and disease reaction of different Brassica germplasm under NDN, UDN against *A. candida* in glasshouse (2015-2016)

NDN	Cotyledonary leaf		True leaf		UDN	Cotyledonary leaf		True leaf	
	DI	DR	DI	DR		DI	DR	DI	DR
Bioysr	37.88 (37.98)	S	35.21 (36.39)	S	Rohini	43.56 (41.29)	S	26.51 (30.98)	MS
Rohini	21.01 (27.28)	MS	30.01 (33.21)	MS	PHR-2	25.56 (30.36)	MS	44.01 (41.55)	S
DRMRIJ 12-51	12.11 (20.36)	MR	22.21 (28.11)	MS	DLSC-1	0.00 (0.00)	I	0.00 (0.00)	I
DRMRIJ 12-02	15.56 (23.23)	MR	21.22 (27.42)	MS	EC 399299	37.56 (37.79)	S	43.56 (41.29)	S
DRMRIJ 12-27	35.89 (36.80)	S	38.01 (38.06)	S	RMM 09-01-1	20.47 (26.89)	MS	27.56 (38.38)	MS
RH 1231	18.56 (25.51)	MR	23.56 (29.03)	MS	DRMR 32	50.51 (45.29)	HS	43.56 (42.82)	S
DRMRIJ 12-41	52.56 (46.46)	HS	43.01 (40.98)	S	PRD 2014-21	45.28 (42.29)	S	38.56 (25.99)	S
DRMRIJ 12-14	31.87 (34.89)	MS	26.92 (37.76)	MS	PRD 2013-3	33.21 (35.18)	MS	46.21 (30.50)	S
DRMRIJ 12-39	27.67 (38.78)	MS	24.67 (34.98)	MS	RMWR 09-5-1	21.21 (27.42)	MS	19.21 (25.11)	MR
DRMR-2035	23.89 (31.08)	MS	28.65 (36.98)	MS	DRMRMJA 35	17.56 (24.77)	MR	25.76 (36.27)	MS
DRMRIJ 12-48	16.89 (24.26)	MR	26.56 (31.02)	MS	DRMR 2035	15.21 (22.95)	MR	18.01 (38.06)	MR
DRMRIJ 12-06	22.21 (28.11)	MS	16.56 (24.01)	MR	ABS(3)-21	12.11 (20.36)	MR	35.01 (37.79)	S
RMWR-09-05-01	27.56 (31.66)	MS	45.02 (42.14)	S	DRMR-73	18.56 (25.51)	MR	38.01 (38.06)	S
DRMRJA 35	28.21 (32.08)	MS	37.89 (37.99)	S	RMM 10-1-1	22.51 (28.32)	MS	37.56 (37.79)	S
DRMRIJ 12-44	14.28 (22.20)	MR	16.01 (23.58)	MR	PRD 2013-8	27.52 (31.36)	MS	54.01 (47.30)	HS
DRMRIJ 12-03	46.56 (43.02)	S	45.01 (42.13)	S	DRMR-2019	21.21 (27.42)	MS	42.01 (40.40)	S
RH 305	50.56 (45.32)	HS	47.68 (43.67)	S	DRMR-72	12.11 (20.36)	MR	55.01 (47.87)	HS
DRMRIJ 12-21	28.01 (31.95)	MS	35.01 (36.27)	S	ABS(3)-16	13.56 (21.60)	MR	32.33 (34.65)	MS
DRMRIJ 12-37	37.01 (37.46)	S	35.56 (36.60)	S	DRMR-312	0.00 (0.00)	I	0.00 (0.00)	I
NPJ 181	12.11 (20.36)	MR	16.01 (23.58)	MR	NPJ-177	11.56 (19.87)	MR	28.67 (32.37)	MS
DRMRIJ 12-26	38.89 (40.99)	S	28.78 (32.89)	MS	PRD 2013-6	22.89 (28.58)	MS	26.21 (30.79)	MS
RMWR-09-05	15.56 (23.23)	MR	17.56 (24.77)	MR	NPJ-177	27.21 (31.44)	MS	31.21 (33.96)	MS
DRMR-2019	19.56 (26.24)	MR	14.56 (22.43)	MR	PRD 2013-9	22.34 (28.20)	MS	34.21 (35.79)	MS

DRMRIJ 12-50	21.21 (27.42)	MS	27.56 (31.66)	MS	PRD 2013-2	21.34 (27.51)	MS	18.56 (25.51)	MR
RH 1234	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	DRMR 100	23.51 (29.00)	MS	28.56 (32.20)	MS
DRMRIJ 12-28	22.51 (28.00)	MS	27.56 (31.20)	MS	ABS(3)-44	22.78 (28.50)	MS	31.56 (34.17)	MS
NDRE-08-14-01	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	DRMR-40	28.01 (31.95)	MS	27.67 (31.73)	MS
DRMRIJ 12-65	22.89 (33.83)	MS	18.21 (25.25)	MR	ABS(3)-15	26.02 (30.67)	MS	35.01 (36.27)	S
DRMRIJ 12-43	30.56 (27.42)	MS	38.01 (38.06)	S	RMM 09-1-1-2	22.23 (28.13)	MS	25.98 (30.64)	MS
DRMRIJ 12-40	31.01 (35.34)	MS	36.02 (36.88)	S	RMM-09-04	44.56 (41.87)	S	21.45 (27.59)	MS
					DRMR-316	47.56 (43.60)	S	43.89 (41.49)	S
					PRE-2011-15	25.41 (30.26)	MS	28.56 (32.30)	MS
					RH-1212	28.01 (31.95)	MS	31.47 (34.12)	MS
					DRMR-7	34.67 (36.07)	MS	28.32 (32.14)	MS
CD 5%	0.51		0.43			0.48		0.56	
CV	1.47		1.16			1.20		1.21	

*Values in parenthesis are angular transformed

DI=Disease index; DR=Disease reactions; I=Immune; MR= moderately resistant; R= Resistant; S=Susceptible; MS=moderately susceptible

Table.7: Disease reaction of different Brassica germplasm under NDN and UDN tested in field and in Glasshouse (2015-2016)

NDN	In Field	In Glasshouse		UDN	In Field	In Glass house	
	Disease reactions	Disease reactions			Disease reactions	Disease reactions	
		Cotyledonary leaf	True leaf			Cotyledonary leaf	True leaf
Bioysr	S	S	S	Rohini	S	S	MS
Rohini	MR	MS	MS	PHR-2	MR	MS	S
DRMRIJ 12-51	S	MR	MS	DLSC-1	ND	I	I
DRMRIJ 12-02	S	MR	MS	EC 399299	MR	S	S
DRMRIJ 12-27	MR	S	S	RMM 09-01-1	MR	MS	MS
RH 1231	MR	MR	MS	DRMR 32	S	HS	S
DRMRIJ 12-41	R	HS	S	PRD 2014-21	S	S	S
DRMRIJ 12-14	MR	MS	MS	PRD 2013-3	S	MS	S
DRMRIJ 12-39	MR	MS	MS	RMWR 09-5-1	R	MS	MR
DRMR-2035	MR	MS	MS	DRMRMJA 35	R	MR	MS
DRMRIJ 12-48	MR	MR	MS	DRMR 2035	R	MR	MR
DRMRIJ 12-06	MR	MS	MR	ABS(3)-21	MR	MR	S
RMWR-09-05-01	S	MS	S	DRMR-73	S	MR	S
DRMRJA 35	R	MS	S	RMM 10-1-1	S	MS	S
DRMRIJ 12-44	MR	MR	MR	PRD 2013-8	S	MS	HS
DRMRIJ 12-03	R	S	S	DRMR-2019	MR	MS	S

RH 305	MR	HS	S	DRMR-72	MR	MR	HS
DRMRIJ 12-21	S	MS	S	ABS(3)-16	S	MR	MS
DRMRIJ 12-37	I	S	S	DRMR-312	ND	I	I
NPJ 181	NG	MR	MR	NPJ-177	MR	MR	MS
DRMRIJ 12-26	S	S	MS	PRD 2013-6	HS	MS	MS
RMWR-09-05	MR	MR	MR	NPJ-177	S	MS	MS
DRMR-2019	MR	MR	MR	PRD 2013-9	HS	MS	MS
DRMRIJ 12-50	NG	MS	MS	PRD 2013-2	S	MS	MR
RH 1234	I	I	I	DRMR 100	S	MS	MS
DRMRIJ 12-28	S	MS	MS	ABS(3)-44	S	MS	MS
NDRE-08-14-01	I	I	I	DRMR-40	S	MS	MS
DRMRIJ 12-65	MS	MS	MR	ABS(3)-15	HS	MS	S
DRMRIJ 12-43	S	MS	S	RMM 09-1-1-2	S	MS	MS
DRMRIJ 12-40	S	MS	S	RMM-09-04	ND	S	MS
				DRMR-316	S	S	S
				PRE-2011-15	HS	MS	MS
				RH-1212	HS	MS	MS
				DRMR-7	S	MS	MS

NG=Not germinated; I=Immune; MR= moderately resistant; R= Resistant; S=Susceptible; MS=moderately susceptible