academicJournals

Vol. 9(47), pp. 3441-3447, 20 November, 2014
DOI: 10.5897/AJAR2014.9252
Article Number: AD153C048593
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Stability analysis in genetically variant oilseed *Brassica* germplasm for *Sclerotinia*-rot resistance

Rajender Singh* and Dhiraj Singh

Department of Plant Pathology, CCS Haryana Agricultural University-Hisar-India.

Received 17 October, 2014; Accepted 31 October, 2014

Ninety two genotypes of oilseed *Brassica juncea* and *Brassica napus* were evaluated over three environments for analysis of stability parameters in relation to *Sclerotinia* rot resistance with responsible characters viz: plant age at the time of inoculation, stem diameter, stem lesion length and percent plant wilted/dead. The analysis of variance for stability revealed the presence of genetic variability in studied material for all the characters. The linear component of Genotype X Environment interactions was significant for all the characters, which indicates that the major portion of interaction was linear in nature and prediction of stable genotype for *Sclerotinia*-rot resistance over the environments was possible. Therefore, genotypes AG Spectrum, RQ011, RH13 and Ringot were found stable for *Sclerotinia*-rot resistance under normal environmental conditions. However, under congenial environmental conditions only six genotypes namely JM018, Ag Outback, Monty, *Brassica juncea* 1, *Brassica juncea* 2 and *Brassica juncea* 3 were most stable for resistance, which may be utilized for further improving genetic base for *Sclerotinia*-rot resistance in oilseed *Brassica*.

Key words: *Brassica juncea, Brassica napus, Sclerotinia*-rot, stability.

INTRODUCTION

Sclerotinia stem rot is a major disease of oilseed *Brassica,* with up to 80% incidence of plants affected in the worst affected crops in the Punjab and Haryana states of Northern India (Kang and Chahal, 2000). In Haryana, 5 to 20% of plants affected by this disease are common, varying with crop growth stage and region (personal communication). Estimated yield losses from *Sclerotinia* stem rot vary throughout the world, with 13% losses in North Dakota and Minnesota (Lamey and Bradley, 2002); 20% (Fitt et al., 1992) to 50% (Pope et al., 1989) in the UK; 0.4-1.5 tonne/ha losses in Australia (Kirkegaard et al., 2006) and 70% in China (Deng and Tang, 2006). Sclerotia of *Sclerotinia sclerotiorum* can germinate either myceliogenically or carpogenically, lead to stem base infection and aerial infections, respectively. Being a ubiquitous necrotrophic pathogen with many different hosts, *Sclerotinia* stem rot is difficult to manage. Primary methods of management rely upon use of non-host crops, fungicide application and manipulation of management practices, but all have been proved unreliable and frequently of little if any economic benefit. The variation among genotypes for *Sclerotinia* stem rot under different environmental conditions was observed by Li et al. (2006). Genetic resistance to *Sclerotinia* stem rot offers the best long term prospect for making oilseed *Brassica* crops more profitable in regions prone to this

*Corresponding author. E-mail: rsb1965@gmail.com

disease. For this reason, using a field stem inoculation technique, we evaluated oilseed *Brassica napus* and *Brassica juncea* genotypes from India, China and Australia for resistance to *S. sclerotiorum* in the field. Inpresent investigation, 92 genotypes of oilseed *Brassica* were evaluated over three environments that is, three crop seasons (2009, 2010 and 2011) to identify stable genotypes with *Sclerotinia* stem rot resistance.

MATERIALS AND METHODS

Seed of accessions of *B. napus* and *B. juncea* was obtained from Australia, China and India through an Australian Centre of International Agricultural Research (ACIAR) collaborative program between these 3 countries. The *B. napus* and *B. juncea* genotypes tested are enlisted in Table 2. Ninety two genotypes of *B*. *napus* and *B. juncea* were tested in the field at the Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar, India. The germplasms were hand sown on 23rd October, 2009, 27th October, 2010, and 25th Oct 2011 in plots with 5 x 2 m. Row to row and plant to plant spacing was maintained 45 and 15 cm, respectively. All recommended agronomic practices were followed, including 100 kg N/ha, 30 kg P_2O_5 /ha fertilizer application at sowing time, two irrigations at 45 and 90 days after sowing in sandy loam soil having pH 8.0 and electrical conductivity 3.5 mMhos/cm. Each genotype was sown in a complete randomised block design (RBD) with three replicates and used for further study. The single isolate of *S. sclerotiorum* (‘CCS HAU-Hisar’) used in this study was isolated from sclerotia collected from diseased *B. juncea* plants stem pith in the previous crop season. Sclerotia were surface sterilized using 0.1% mercuric chloride solution in distilled water, cut in two pieces with sterilized Gilllete platinum blade and plated cut side face down on potato dextrose agar medium in 90 mm Petri® plates under aspetic conditions in laminar flow. Thirty plants of each genotype within each replication were picked at random and inoculated at the flowering stage (when 50% of plants in the row had at least one opened flower). This was stage GS 61 BBCH on the scale of Lancashire et al. (1991) and equivalent to stage GS 41-42 on the scale of Harper and Berkenkamp (1975). Stem inoculation was carried out according to the method of Buchwaldt et al. (2005) in all crop seasons. A single 5 mm diameter agar plug disc cut from the *S. sclerotiorum* colony edge of 3 to 4 days old culture growing on a glucose rich medium (Glucose 20 g, NaOH 1 g, NH_4 NO_3 2 g, $MgSO_4$ 7 H_2O 0.1 g, Malic acid 3 g, KH_2 PO_4 1 g and Agar 30 g in 1 L of distilled H_2O) was used to inoculate each plant. The agar plug was placed mycelium side up on a small piece of Parafilm® (about 5 cm long). The plug was then placed on to the stem at the first internode above the middle internode of each stem (with the mycelium in contact with stem) by wrapping the Parafilm® strip around the stem to secure the plug onto the stem. A wet cotton wool swab was also wrapped around the stem just above the top of the Parafilm® strip to maintain high humidity during the infection period. The observation on four characters viz. plant age at inoculation (days) time, stem diameter (mm), stem lesion length (mm) and wilted/dead plant (%) were recorded. The statistical analysis for stability was carried out according to the method of Eberhart and Russell (1966).

RESULTS

The pooled analysis of variance (Table 1) revealed that mean sum of squares due to Genotype (G) × Environment (E) interaction tested against pooled error and was found significant for wilted plants (%). It indicated that genotypes and environments not independent in causing variation but also have involvement of G×E interaction in the expression of wilted plant (%). Non significant G×E interaction observed for plant age at inoculation, stem diameter and stem lesion length indicate that these characters are least influenced by the environments. The absence of differential response of the genotypes for plant age at inoculation, stem diameter and stem lesion length in the present investigation indicates the stable expression of these characters.

Highly significant environmental (linear) variance for all the characters suggested that variation among the environments was linear. A linear environmental variance signifies unit changes in environmental conditions. The G×E (linear) variance was non significant for plant age at inoculation, stem diameter and stem lesion length implying thereby, differential performance of genotypes under diverse environments with nearly uniform reaction norms.

On the other hand, non significant pooled deviations for all the characters suggested that performance of different genotypes non-fluctuated significantly from their respective linear path of response to environments (Table 1). In other words, the predictable environments formed the major portion of G×E interactions. Moreover, by observing the individual varietal fluctuation from linearity, it becomes clear that only a very few genotypes fluctuated significantly from linearity. The environmental index (Ij) for all the environments and for all the characters was estimated. A critical analysis revealed that E_3 that is, environmental condition prevailed during 25th Oct 2011 sown genotype expressed high environmental index for the characters viz. plant age at inoculation, stem diameter, and wilted plant (%) and E_2 that is, environmental condition prevailed during 27th Oct 2010 sown genotype for stem lesion length (Table 2).

On the contrary, E_2 exhibited lowest value for plant age at inoculation time, and E_1 that is, environmental condition prevailed during 23rd 2009 sown genotype exhibited lowest value for stem diameter and stem lesion length (Table 2).

Plant age at inoculation (days)

On mean basis, 48 genotypes were early in plant age at inoculation (days) time and 44 genotypes were older in plant age. Out of 92 genotypes, only 8 genotypes expressed below average (b_i<1) response, 27 genotypes expressed above average (b_i>1) response and remaining 57 genotypes exhibited average response value of regression coefficient (Table 2). A consideration of the stability parameters together, 57 genotypes (30 below mean and 27 above mean) were average in response (b_i = 1) and good in stability (deviation from regression that is, S^2_{di}=0).

Table 1. Analysis of variance for stability (Eberhart and Russell, 1966).

Source of variation	d.f.	Mean sum of squares			
		Plant age at inoculation (days)	Stem diameter (mm)	Stem lesion length (mm)	Wilted plant (%)
Genotypes	91	399.852 $^{x\ **++}$	60.697 $^{x**++}$	2794.103 $^{x**++}$	878.468 $^{x**++}$
Environment	2	28.691 $^{x**++}$	10.120 $^{x**++}$	93.644 $^{x**++}$	67.068 $^{x**++}$
Genotype X Environment	182	0.085^{NS++}	0.061 ^{NS}	1.179 $^{NS++}$	23.592**$^{++}$
Env. + (GXE)	184	0.393^{++}	0.170^{++}	2.184^{++}	24.065^{++}
Env. (linear)	1	57.382***$^{++}$	20.239***$^{++}$	187.288***$^{++}$	134.136***$^{++}$
En x Gen (linear)	91	0.123^{++}	0.030^{NS}	1.942^{++}	36.989**
Pooled deviation	92	0.041^{NS}	0.90 ^{NS}	0.411 ^{NS}	10.084 **
Pooled error	546	2.686	1.083	5.086	4.917

** Significant at 1% level of significance against pooled errors, $^{++}$ Significant at 1% level of significance against pooled deviation, ^{x}Significant against Genotype (G) x Environment (E).

Stem diameter (mm)

An examination of individual stability parameter for stem diameter (Table 2) revealed that as many as 43 genotypes had above average mean performance and 49 genotypes had below average mean performance (Table 2). Further, all the genotypes were found to be stable (S^2_{di}=0). Majority of genotypes were having average response for stem diameter (b_i = 1). Only 15 genotypes exhibited below average response (b_i<1) and only one genotype that is, Rivette exhibited above average (b_i>1) response.

Stem lesion length (mm)

On the basis of mean stem lesion length (mm) it was observed that 42 genotypes exhibited below mean, 6 genotypes average mean and 50 genotypes above mean for stem lesion length. Further, all the genotypes exhibited non significant S^2_{di} value indicating the absence of non linear component of G×E interaction. Out of 92 genotypes, only 38 genotypes exhibited totally absence of G×E interaction having b_i = 1 and S^2_{di}=0, 17 genotypes (b_i > 1) and 55 genotypes (bi <1) exhibited the presence of linear component of G×E interaction (Table 2).

Considering the three stability parameters, simultaneously (high resistance/ small stem lesion, b_i = 1 and S^2_{di} = 0) RH 13, Ringot, *Brassica juncea* 1, *Brassica juncea* 2, *Brassica juncea* 3 and RQ 011 were highly resistant and stable for stem lesion length over the environments or three crop seasons (Table 2). Moreover, Ag outback was highly resistant and suitable for conducive environment (small lesion length, b_i <1, S^2_{di} = 0) for disease development against CCSHAU-Hisar isolate.

Wilted/ dead plants

An examination of data on wilted /dead plant reflected that 38, 13 and 41 genotypes were below mean, at average mean and above mean, respectively. In majority of genotypes linear components of G×E interaction was noticed, except 31 genotypes which showed the absence of linear component of G×E interaction. However, the majority of genotypes (81) exhibited the non significant for S^2_{di} value means absence of non-linear component of G×E interaction (Table 2). Out of top resistant genotypes against *Sclerotinia* stem rot, only Ag spectrum was found suitable for general environment conditions (highly resistant, b_i = 1, S^2_{di} = 0) and six other (JM018, Ag outback, Monty, *B. juncea* 1, *B. juncea* 2 and *B. juncea* 3), were suitable for conducive environment(highly resistant, b_i<1, S^2_{di} = 0) of disease development (Table 2). In contrast to this, JM 3 was highly susceptible to *Sclerotinia* stem rot; but it was also stable susceptible (S^2_{di} = 0 and b_i = 1).

DISCUSSION

On the basis of environmental index, it was found that E_3 was most conducive environment for disease development. The estimates of three stability parameters namely X, b_i and S^2_{di} (Table 2) revealed that the non significant value of S^2_{di} indicating thereby the totally absence of nonlinear component of G×E interaction in all the genotypes

Table 2. Estimates of stability parameters for *Sclerotinia* stem rot in oilseed *Brassica.*

Genotype	Plant age at inoculation (days)			Stem diameter (mm)			Steam lesion length(cm)			Wilted/dead plants (%)		
	Mean	bi	S^2_{di}	Mean	bi	S^2_{di}	Mean	bi	S^2_{di}	Mean	bi	S^2_{di}
'JN004'	81.222	1.179	-2.590	14.222	0.576*	-1.082	70.556	0.361*	-5.056	37.404	0.984	-4.891
'JN010'	79.778	0.014	-2.613	15.222	0.576*	-1.082	98.222	0.361*	-5.056	54.667	0.567*	-4.720
'JN028'	81.000	0.596*	-2.686	10.222	0.576*	-1.082	55.000	0.535*	-4.114	25.000	0.000*	-4.918
'JN031'	81.222	1.179	-2.590	11.222	0.576*	-1.082	76.556	0.249*	-4.694	34.703	-0.606*	-4.706
'JN032'	83.778	0.014	-2.613	13.333	0.922	-1.048	105.000	0.211	-4.288	44.952	1.600	-4.223
'JN033'	79.000	0.596*	-2.686	11.222	0.576*	-1.082	82.333	0.324*	-5.078	29.887	0.000*	-4.918
'JM016'	80.444	1.761	-2.324	15.222	0.576*	-1.082	96.222	0.143*	-5.054	48.144	1.969*	-4.808
'JM018'	85.000	0.596*	-2.686	12.333	0.807	-1.004	25.667	0.324*	-5.078	8.256	0.008*	-4.885
'JO008'	81.000	0.596*	-2.686	14.444	1.153	-1.079	82.889	0.249*	-4.694	27.000	-0.035*	-4.253
'JO009'	81.444	0.014	-2.613	16.222	0.576*	-1.082	97.444	0.286*	-4.957	47.397	0.773*	-4.876
'JR042'	83.111	0.887	-2.659	15.444	1.268	-0.918	92.556	0.467*	-5.012	44.033	0.177*	-4.741
'JR049'	81.222	1.179	-2.590	18.222	0.576*	-1.082	48.444	0.286*	-4.957	27.444	0.981	-4.912
'Lantern'	101.667	0.596	-2.686	23.333	0.922	-1.048	94.444	0.286*	-4.957	26.627	-0.209*	-4.824
'Ag Outback'	102.222	1.179	-2.590	16.333	0.807	-1.004	2.444	-0.038*	-5.015	1.813	-0.014*	-4.918
'Trigold'	102.222	1.179	-2.590	14.444	1.153	-1.079	98.222	0.143	-5.054	52.000	1.914	-4.036
'Monty'	101.778	0.014	-2.613	16.444	1.153	-1.079	30.111	-0.038	-5.015	6.774	-0.012*	-4.844
'Rainbow'	101.000	0.596	-2.686	14.444	1.153	-1.079	59.333	0.422	-1.894	20.111	-0.012*	-4.844
'Rivette'	100.667	0.596	-2.686	22.556	1.614*	-0.693	85.889	0.791	-4.953	34.703	-0.252	-3.227
'RQ 011'	101.222	1.179	-2.590	12.222	0.576*	-1.082	60.778	1.047	-5.021	10.000	0.000	-4.918
'Tranby'	100.889	0.305*	-2.671	16.222	0.576*	-1.082	56.444	0.505*	-5.086	19.889	0.012*	-4.844
Av Sapphire	101.333	1.193*	-2.685	16.333	0.922	-1.048	83.778	0.505*	-5.086	27.108	1.406	-4.170
'BST 702N2'	100.889	0.305*	-2.671	16.556	1.499	-1.059	65.667	0.648*	-5.052	30.370	0.599*	-4.839
'RQ 001-02M2'	102.000	0.590	-2.686	19.333	0.922	-1.048	76.556	0.467*	-5.012	40.778	0.413*	-4.648
'RR 013'	103.333	0.596*	-2.686	15.556	1.499	-1.059	107.778	0.505*	-5.086	58.999	0.933	-3.892
'RR 009'	102.111	0.887	-2.659	17.556	1.499	-1.059	89.889	0.467*	-5.012	47.700	-0.004*	-4.910
'Surpass 400'	101.889	0.902	-2.675	18.556	1.499	-1.059	115.778	0.505*	-5.086	70.949	1.387*	-4.726
'RR005'	102.111	1.484*	-2.652	21.667	0.922	-1.048	94.333	0.648*	-5.052	30.663	0.780*	-4.915
'scar'	102.222	1.179	-2.590	19.556	0.576*	-1.082	119.000	0.648*	-5.052	72.292	0.784*	-4.916
'Mystic'	101.889	0.902	-2.675	24.444	1.153	-1.079	95.889	0.678*	-3.727	67.579	-0.097	0.098
'RR 001'	102.000	1.193*	-2.685	25.111	0.231	-1.021	85.556	0.467*	-5.012	41.073	1.587*	-4.629
'Charlton'	101.778	0.887	-2.659	18.778	1.153	-1.079	83.444	1.047	-5.021	31.182	-0.126	3.492
'Skipton'	102.000	1.193*	-2.685	23.333	0.922	-1.048	110.667	0.430	-4.795	37.518	0.406*	-4.802
'Trilogy'	101.667	0.319	-2.528	19.444	1.153	-1.079	94.333	0.324*	-5.078	40.667	0.567*	-4.720
'Ag Spectrum'	102.222	1.179	-2.590	21.556	1.499	-1.059	28.889	-0.075*	-4.802	10.111	-0.012	-4.844
'TQ0055-02W2'	101.222	1.775*	-2.578	20.444	1.153	-1.079	107.000	2.711*	-3.384	44.444	1.583*	-4.720

Table 2 Contd.

‘Purler’	101.000	0.596	-2.686	21.556	1.383	-0.986	75.444	1.476*	-5.005	37.887	0.567*	-4.720
‘HNS0501’	100.889	0.902	-2.675	19.778	1.153	-1.079	79.222	1.333*	-5.075	37.888	0.768*	-4.815
‘GSL-I’	100.667	1.193	-2.685	18.444	1.268	-0.918	102.222	1.770*	-4.723	31.556	2.386*	-4.036
‘JMO 6001’	81.000	0.596	-2.686	9.556	1.499	-1.059	79.556	1.657*	-5.047	30.667	0.567*	-4.720
‘JMO 6002’	81.000	1.193*	-2.685	11.333	0.807	-1.004	73.667	0.648*	-5.052	26.889	-0.201*	-4.902
‘JMO 6003’	81.111	0.887	-2.659	9.333	0.807	-1.004	155.222	1.763	-4.671	60.778	0.768*	-4.815
‘JMO 6004’	80.889	0.902	-2.675	11.333	0.807	-1.004	127.333	0.859	-3.922	54.441	1.583*	-4.720
‘JMO 6006’	81.222	0.902	-2.675	12.444	1.268	-0.918	119.000	1.190*	-5.081	46.998	1.548*	-4.780
‘JMO 6010’	81.333	0.596*	-2.686	14.556	1.499	-1.059	93.000	1.190*	-5.081	46.144	1.011	-4.427
‘JMO 6011’	81.111	0.611	-2.623	9.556	0.576*	-1.082	85.778	1.047	-5.021	37.444	0.768*	-4.815
‘JMO 6012’	81.000	1.193*	-2.685	12.444	1.268	-0.918	85.778	0.829*	-5.077	40.889	0.969	-4.879
‘JMO 6013’	81.000	1.193*	-2.685	12.444	1.268	-0.918	82.889	1.009	-5.086	39.222	1.819	-3.003
‘JMO 6014’	81.111	0.887	-2.659	10.556	0.576*	-1.082	114.222	1.446	-4.602	38.441	2.575*	-4.292
‘JMO 6015’	81.333	1.193*	-2.685	9.222	0.576*	-1.082	115.222	1.552*	-5.024	41.516	0.902	-1.895
‘JMO 6018’	81.000	1.193*	-2.685	22.444	1.153	-1.079	133.000	1.084	-4.814	57.444	0.768*	-4.815
‘JMO 6019’	81.222	0.902	-2.675	19.444	1.153	-1.079	150.778	0.061	-1.242	60.778	0.768*	-4.815
‘JMO 6020’	80.889	0.902	-2.675	18.444	1.153	-1.079	108.556	0.467*	-5.012	41.923	1.639	-3.266
‘JMO 6021’	80.667	1.193*	-2.685	13.222	0.576*	-1.082	86.333	0.430	-4.795	38.329	1.323	-3.841
‘JMO 6026’	81.000	1.193*	-2.685	11.444	1.038	-0.802	92.000	0.430	-4.795	44.441	1.583*	-4.721
‘Loiret’	103.889	0.902	-2.675	11.444	1.153	-1.079	115.889	0.791	-4.953	38.182	1.895*	-4.906
‘Ekla’	102.333	1.193*	-2.685	11.333	0.807	-1.004	72.778	0.829*	-5.077	24.159	-0.068	-2.450
‘Montana’	102.000	1.193*	-2.685	16.444	1.153	-1.079	123.000	1.190*	-5.081	55.146	1.934*	-4.680
‘ RH13	101.667	1.193*	-2.685	11.556	1.499	-1.059	5.333	-0.113	-4.446	1.804	0.000*	-4.916
‘Ringot	102.111	1.484	-2.652	12.556	1.268	-0.474	25.111	-0.038	-5.015	1.821	-0.000*	-4.917
‘RK 2	101.222	0.902	-2.675	15.222	0.296	-0.892	59.778	1.047	-5.021	13.723	-0.026*	-4.554
‘Amora III	101.556	0.902	-2.675	15.111	0.074	1.035	140.778	0.829*	-5.077	44.887	1.298*	-4.911
RL	100.667	1.193*	-2.685	12.333	0.922	-1.048	85.556	0.685*	-5.080	40.552	1.004	-4.536
‘‘Haoyou II’	104.111	0.887	-2.659	14.556	1.499	-1.059	82.556	0.685*	-5.080	34.813	0.049	-3.633
‘Tunliuhuangiie’	104.333	2.428	-2.142	16.444	1.153	-1.079	105.889	1.770	-4.723	37.222	1.181*	-4.879
‘Qianxianjiecai’	105.222	1.775*	-2.578	19.222	0.692	-0.892	123.444	2.131*	-4.483	64.667	25.872*	93.803*
Yilihuang’	104.889	1.498*	-2.679	18.778	1.960	-0.965	111.667	2.275	-4.730	46.776	5.590	2.081
‘Hatianyoucai’	104.889	0.902	-2.675	24.556	0.692	-0.892	107.889	5.347*	-0.776	46.293	-1.024*	-3.769
‘Jinshahuang’	104.778	1.484*	-2.652	18.556	0.692	-0.892	99.667	2.056*	-5.027	41.342	8.422	14.334
‘Manasihuang’	105.111	1.484*	-2.652	16.778	1.383	-0.319	28.333	-0.113	-4.446	13.803	21.704*	74.220*
Brassica juncea 1	105.556	0.902	-2.675	16.444	1.268	-0.918	20.111	-0.038	-5.015	1.798	0.023*	-4.917
‘Brassica juncea 2’	106.000	0.319	-2.528	16.556	1.614	-0.693	25.333	-0.113	-4.446	1.801	-0.023*	-4.918
‘Brassica juncea-3’	105.889	0.902	-2.675	15.667	1.845	-0.943	30.111	-0.038	-5.015	1.802	-0.006*	-4.916

Table 2 Contd.

'Ashirwad'	78.111	1.484*	-2.652	8.222	0.576	-1.082	86.000	1.408*	-4.902	18.646	-14.810*	100.29*
'Aravali'	78.111	2.400*	-2.649	9.222	0.576	-1.082	94.667	0.866*	-5.058	29.406	-1.357*	-3.509
'Basanti'	78.556	0.902	-2.675	9.889	0.576	-1.082	55.556	0.685	-5.080	23.667	5.990	3.442
'CS 52'	77.889	0.902	-2.675	8.222	0.692	-0.892	53.333	1.732*	-4.973	20.222	-0.555	-4.404
'CS 54'	77.444	1.207	-2.632	8.333	0.807	-1.004	69.889	1.228	-4.969	24.740	-4.107	4.418
'GM 2'	77.889	0.902	-2.675	9.556	1.268	-0.474	89.222	1.770	-4.723	33.219	-5.623	7.051
'Geeta'	80.000	1.193*	-2.685	9.444	1.153	-1.079	92.889	1.228	-4.969	40.062	-1.376	2.363
'GM 3'	77.889	0.902	-2.675	8.333	0.807	-1.004	71.111	4.624*	-2.100	31.257	11.102*	38.193*
'Jagannath'	79.000	1.193*	-2.685	9.444	1.038	-0.802	94.667	0.866	-5.058	28.888	-2.896	8.285
'JM 1'	78.111	1.484*	-2.652	8.444	1.153	-1.079	96.778	2.674	-4.009	39.740	-8.336	50.132*
'JM 2'	78.222	1.179	-2.590	8.444	1.153	-1.079	105.889	1.228	-4.969	60.443	-13.906*	60.912*
'JM 3'	78.778	0.611	-2.623	11.444	1.153	-1.079	123.222	1.770	-4.723	72.618	-2.427	3.509
'Laxmi'	77.889	1.498*	-2.679	9.333	0.807	-1.004	109.222	1.770	-4.723	66.518	8.343*	16.277*
'Maya'	77.889	0.902	-2.675	12.556	1.383	-0.986	110.778	4.300*	-1.771	61.814	2.854*	-3.412
Pusa Mahak	76.667	1.512	-2.557	9.222	0.576	-1.082	98.667	0.866	-5.058	52.811	9.886*	25.915*
RGN 13'	76.889	0.902	-2.675	12.556	1.499	-1.059	90.000	1.408	-4.902	42.933	5.308	5.747
'Swaran Jyoti'	75.778	1.803*	-2.641	9.333	0.807	-1.004	95.222	2.854*	-3.821	36.257	5.276	3.971
'Vasundra'	75.889	0.902	-2.675	11.222	0.461	-0.834	69.333	1.951*	-4.610	33.394	3.447*	-3.403
'Kranti'	75.889	0.902	-2.675	9.556	1.268	-0.474	99.222	1.770	-4.723	33.083	-1.266	-4.710
Urvashi	77.778	0.611	-2.623	12.222	0.461	-0.834	102.556	0.685*	-5.080	47.619	-11.534*	45.434*

S^2_{di}=deviation from regression, a parameter of stability, b_i=regression coefficient, a parameter of stability test.

However, only linear component of G×E interaction was noticed which is expressed by significant value of regression coefficient (b_i = 1) only in 35 genotypes for this characters. Rivette exhibited above average (b_i>1) response showing their adaptability to favourable environmental conditions of disease development.

Out of 92 genotypes, only 16 genotypes were found to have b_i significant values indicating thereby the presence of linear component of G×E interaction in these genotypes only. Moreover, S^2_{di} value for all the genotypes were found non significant indicating totally absence of non-linear component of G×E interaction for stem diameter.

On stability parameters basis (high resistance/ small stem lesion, b_i = 1 and S^2_{di} = 0) RH 13, Ringot, *B. juncea* 1, *B. juncea* 2, *B. juncea* 3 and RQ 011 were highly resistant and stable for small stem lesion length over the environments. Ag spectrum was found suitable for general environment conditions (small lesion length, b_i = 1, S^2_{di} = 0) for disease development. Six genotypes that is, JM018, Ag outback, Monty, *B. juncea* 1, *B. juncea* 2 and *B. juncea* 3, were stable and suitable for conducive environment of disease development (highly resistant, b_i<1, S^2_{di} = 0). In contrary to it, JM 3 was highly susceptible to *Sclerotinia* stem rot, but it was also stable susceptible (S^2_{di} = 0 and b_i = 1).

The genotypes showing resistance against *Sclerotinia* stem rot as indicated by lesser number of wilted / dead plant were also exhibited short stem lesion length, wider stem diameter and older plant age for inoculation. Similar observations have also been reported by Li et al. (2006) that there is significant positive linear relationship between plant death and stem lesion length. Hence, the identified stable resistance genotypes could be utilized directly as cultivar after evaluation over time and space if found suitable. Moreover, these should be incorporated in resistance breeding programme to enhance the genetic level of resistance in future cultivars against recalcitrant necrotroph.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Buchwaldt L, Hegedus D, Li R, Lydrate D, Rimmer R (2005). Priminary mapping of physiological resistance to *Sclerotinia sclerotiorum* in Brassica napus: (In) Proceeding of 13th International Sclerotinia Workshop, California. P. 45.

Deng HM, Tang H (2006). Study on the regulatory of outbreak and control of rapeseed stem white rot. China Plant Prot. 26:16-18.

Eberhart SA, Russell WA (1966). Stability parameters for comparing varieties. Crop Sci. 6:36-40. http://dx.doi.org/10.2135/cropsci1966.0011183X000600010011x

Fitt B, McCartney HA, Davies JML (1992). Strategies for control of Sclerotinia. Agronomist 1:12-13.

Harper FR, Berkenkamp B (1975). Revised growth stage key for *Brassica campestris* and *B. napus*. Canadian J. Plant Sci. 55:657-658.http://dx.doi.org/10.4141/cjps75-103

Kang IS, Chahal SS (2000). Prevalence and incidence of white rot of rapeseed and mustard by *Sclerotinia sclerotiorum* in Punjab. Plant Dis. Res. 15:232-233.

Kirkegaard JA, Michael AE, Hamblin RP, Strange S (2006). Effect of blackleg and Sclerotinia stem rot on canola yield in high rainfall zone of Southern New South Wales. Aust. J. Agric. Res. 57:201-212. http://dx.doi.org/10.1071/AR05179

Lamey A, Bradley CA (2002). Sclerotinia rot of canola. Biology and management. NDSU Extention Service North Dakota State University. PMCid:PMC1769595

Lancashire PD, Bleiholder H, Van Den Boon T, Langeluddek P, Stauss R. Elfriede W, Witzenberger A (1991). A uniform decimal code for growth stages of crops and weeds. Ann. Appl. Biol. 119:561-601. http://dx.doi.org/10.1111/j.1744-7348.1991.tb04895.x

Li C, Sivasthamparam K, Fu TD, Li YC, Li SY, Barbetti MJ (2006). Expression of field resistance under western Australian conditions of Sclerotinia sclerotiorum in Chinese and Australia of *Brassica napus* and *Brassica juncea* germplasm and its relation with stem diameter. Australian J. Agric. Res. 57:1131-1135. http://dx.doi.org/10.1071/AR06066

Pope SJ, Vansey FL, Sweet JB (1989). Susceptibility of cultivars of oilseed rape to *Sclerotinia sclerotiorum* and effect of infection on yield. Aspects Appl. Biol. 23: 451-57.