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Research Article

SCREENING OF DIFFERENT CULTIVAR OF INDIAN MUSTARD FOR PARTIAL RESISTANCE TO *ALTERNARIA BLIGHT*

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Abstract: Partial resistance to *Alternaria blight* (*Alternaria brassicae*) was assessed in 15 genotypes of Indian mustard under field conditions. four genotypes *viz*., NDRE-7, NDWR-05-1, NDRE-4 and NDRE-16 exhibited partial resistance and had lowest per cent blight cover, minimum number of spot/ 10 cm^2, size of spot (mm), sporulation (conidia/spot), disease severity (PDI), apparent infection rate, leaf defoliation, AUDPC and maximum yield, respectively. Numbers of spot were positively & significantly correlated with size of spot (0.949), disease index (0.905), leaf defoliation (0.954), AUDPC (0.917), infection rate (0.878), except sporulation and negatively correlated with yield kg/ha (-0.952).

Keywords: *Mustard, Alternaria, AUDPC, Brassica, Genotype*

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Introduction

Oilseed crops play an important role in agricultural economy of India. Our country is the fourth largest oil economy in the world after the U.S., China and Brazil in terms of vegetable oils. Out of annual commercial cultivation of 7 edible oilseeds (groundnut, rapeseed-mustard, sesame, linseed, soybean, safflower and niger) in India, rapeseed-mustard (Brassica species.) contributes 28.6% in the total production of oilseeds. The edible oil industry is one of the most vibrant sectors of the Indian agriculture economy. The county ranks first in the world in the production of castor, safflower, sesame and niger; second in groundnut and rapeseed-mustard; third in linseed and fourth in soybean.

The cultivation of oilseed crops along with many other minor oilseed crops has been possible due to favorable agro ecological conditions. Rapeseed and mustard belongs to family Brassicaceae which is grown in Northern India comprising traditionally grown indigenous species namely Indian mustard (*Brassica juncea*), brown sarson(*Brassica campestris* var. brownsarson), yellow sarson (*Brassica campestris* var. yellow sarson) toria (*Brassica campestris* var. toria) and Taramira (*Eruca sativa*) along with nontraditional species like gobhisarson *(Brassica napus*), white mustard (*Brassica alba*) and Ethiopian mustard (*Brassica carinata*). It is the most important group of rabi oilseed crops and contributes a major share to the vegetable fat economy of the country.

Rapeseed-mustard oil is the cooking medium and dietary fat of a very large population in northern and eastern states in our country. Rapeseed-mustard oil is characterized by a low level of saturated fatty acids, a relatively high level of mono unsaturated fatty acids, moderate level of polyunsaturated fatty acids and an appreciable amount of the α-linolenic fatty acid. The content of saturated fatty acids, which are known to increase cholesterol levels (*viz*., Lauric, Myristic and Palmitic), is only 4%. Higher levels of monounsaturated and polyunsaturated fatty acids provide the advantage on lowering total cholesterol of plasma and low-density lipoproteins (LDL) cholesterol as well as protective against oxidation of LDL.

The fairly high level of phyto-sterols present in the oil are also reported to lower plasma cholesterol level of absorption of dietary cholesterol and the reabsorption of billary cholesterol. Oil and meal quality have an important place in rapeseed-mustard breeding programme. Quality of oil is important for good health of human being (nutrition point of view, keeping quality (shelf life of oil) and industrial uses. Oil quality and usage of oil, by and large, is determined by the proportion (percentage) of various fatty acids present in oil. Meal quality is determined by levels of anti-nutritional factors particularly by glucosinolate and proportional protein and fiber contents. Canola is a registered name given by Western Canadian Oilseed Crusher's Association for varieties having less than 2 per cent erucic acid in oil and less than 22 µ moles of glucosinolate/g in defatted seed meal. Indian cultivars have high erucic acid (40-50%) in oil and high glucosinolate (80-120 µ moles/g) in seed meal. So there is an urgent need to make concerted efforts for breeding varieties with improved quality of oil (< 2% erucic acid) and meal (≤ 22 µ moles/g glucosinolate) at par with international quality norms. Edible oils or fats are associated with an increased risk of heart diseases, so major emphasis should be given on quality of oil and fat, which are very high in polyunsaturated fatty acids (PUFA). PUFA causes Atherosclerosis' a disease in adults and uipidosis in children, which interferes in myocardial conductance and peripheral vascular system, thereby decreasing coagulation time and increases blood cholesterol. Concentrated scientific approach for the improvement of quality of oil is the need of the hour. Among oilseed crops, rapeseed-mustard occupies a prominent position in the country. Rapeseed-mustard are major rabi oilseed crops of the northern India. The oilseed crop is predominantly cultivated in Assam, Bihar, U.P, W.B, Rajasthan and North Eastern states particularly Meghalaya & Sikkim, (North & Central India) India occupies the second position in area after China and third position in production of rapeseed-mustard in the world after China and Canada. In India, it is the second most important edible oilseed crop after groundnut sharing 25-30.0% in the India's oilseed economy.

Table- Research Project on Rapeseed-mustard pathology, Planning and Review session-2009-10

SN	Rating scale (0-6)	Description of scale	Host reaction
1	0	No visible symptoms	Free
2	1	Up to 5% leaf area covered	Highly Resistant
3	2	5-10% leaf or pod area covered with small pin head spots on the leaves and superficial pinhead spots on pods	Resistant
4	3	10-20% leaf or pod area covered with small spots on the leaf and superficial pin head spots on pods	Moderately Resistant
5	4	20-30% leaf or pod area covered with bigger spots with initiation of coalesces on leaves and deep lesion on pods	Moderately Susceptible
6	5	30-50% leaf or pod area covered with bigger spots commonly coalescing spots on leaves and deep lesion on pods	Susceptible
7	6	More than 50% leaf or pod area covered giving blighting appearance	Highly Susceptible

The share of oilseeds is 14.1% out of the total cropped area in India, rapeseed-mustard accounts for 3% of it. Among the entire oilseed crops producing states in India and in U.P. the area under cultivation is 6.39 lakh hac, with production of 7.9 lakh metric tonnes and productivity of 12.36 q/ha [1]. This lower production is attributable mainly due to biotic and abiotic stresses. Among the biotic stresses, fungal folior diseases, *viz*., *Alternaria blight* caused by *Alternaria brassicae* (Berk) Sacc. and *Alternaria brassicicola* (Schwin) Wiltshire, White rust caused by *Albugo candida* (Lev.) Kunze, Downy mildew caused by *Peronospora parasitica* (Pers.) ex Fr. and Powdery mildew caused by *Erysiphe cruciferarum* Opiz ex. Junell are most important and individually or collectively, cause enormous losses. Among the various diseases, *Alternaria blight* caused by *Alternaria brassicae* (Berk) Sacc. and *Alternaria brassicicola* (Schwin) Wiltshire is one of the most severe yield destabilizing factors causing reduction from 35 to 45 per cent and inflicts very severe losses up to 70 per cent in yield of rapeseed and mustard crops of yellow and brown sarson [2-4]. The disease also adversely affects quality by reducing seed size, impairing seed colour and oil content [5].

Materials and Methods

The present investigation was carried out at the Student's Instructional Farm (2013-2014) and in the Department of Plant Pathology, College of Agriculture, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P). The details of the experiment are described as below:

Geographical and climatic conditions of the location

Geographical location of Faizabad district falls at 26.47 0N latitude and 82.12 'E longitudes at an altitude of 113 m from the mean sea level. The region comes under sub-humid and sub-tropical climate receiving mean annual rainfall of about 1200 mm. About 80 per cent of the total rainfall is received from mid June to end of September and the period is known as monsoon months. The winter months are very cold, whereas summer moths are very hot and dry. Generally hot winds start from the end of April and continue till the onset of monsoon.

Plan of experiments

The experiments were carried out in the field with the procurement of seeds, fertilizers and test materials like micro-nutrients, and chemicals well in advance. Different varieties/ genotypes of *Brassica juncea* were procured from the All India Co-ordinated Research Project on Rapeseed-Mustard, Department of Genetics and Plant Breeding of the University.

Land preparations and raising of crop

The land was well prepared by one deep ploughing with soil turning plough, followed by two cross harrowing. Entire field was marked with rope to have sowing in rows at 30 cm spacing between two rows. Field was also divided in blocks and plots to provide channels for irrigation and drainage.

Fertilizers applications

The recommended dose of fertilizers (N: P: K-120:60:60kg/ha) was applied in the form of urea, single super phosphate and murate of potash. Half dose of nitrogenous fertilizer and full dose of phosphorus and potash were applied in furrows as basal dressing at the time of sowing.

Studies on development of *Alternaria blight* in different genotypes

This experiment was conducted during Rabi 2013-2014 at Student's Instructional Farm of the N.D. University of Agriculture and Technology, Kumarganj, Faizabad by planting fifteen genotypes of the Indian mustard namely NDWR-05-1, NDRE-22, Varuna, NDR-8501, NDRE-7, NDR-2011, NDRS-2010, NDRE-4, PRB-2004-3, Ashirwad, JD-6, NDRE-8213, NDYR-32, NDRE-16 and NDYR-8. Each genotypes were sown in well prepared and fertilized field in five lines of three meter length having spacing of 30 cm from line to line and 10 cm from plant to plant on October 22, 2013. All the entries were also flanked by two rows of susceptible check. All the cultural operations were adopted as per recommendation for raising the good crop. The details of layout have been given and other details of the experiment are as follows:

Layout:
Date of sowing: 22-10-2013
Design: RBD
Plot size: 3m ×1.5m
Spacing: 30 cm × 10cm
Replication: 3
Fertilizers: 120:60:60 NPK kg/ha

Observations recorded

After germination the crop was regularly observed for first appearance of disease. The number of spots was counted per 10 cm^2 leaf area on different tagged leaves with the half of a glass slide, on which 5x2 cm^2 area was marked with permanent markers. Observations were taken on lower leaf, middle leaf and upper leaf at five places per leaf lamina on upper surface of leaf, starting from lower most leaf to the upper most fully developed leaves. This method of counting of spots was followed in all the successive observations. Average number of spots was calculated. Alternaria blight spots were also counted on pods, one week prior to maturity of the plant. A total of twenty five pods @ 5 pods per plant per genotype per replication were observed and average number of spots per pod was calculated. Each plant, five leaves were randomly selected on which diameter of randomly selected spots were measured in mm. Average size of leaf spot in each genotype was calculated. Five largest spots per infected pod of the selected plants were measured and average was calculated on the basis of fifty spots /genotype.The spore production in different genotypes at different intervals on spots of *Alternaria blight*, the affected leaves were thoroughly washed in running tap water and the lesion of similar size were taken at different intervals and separated by cork borer (8mm). These lesions were surface sterilized with 0.1% mercuric chloride and further washed repeatedly in sterilized distilled water. Sporulation was observed by suspending sporulated lesions in vials containing a mixture of distilled water + lactophenol in the ratio of 9:1. These lesions were than shaken vigourously and scrapped with the help of an camel hair brush. The conidia were counted with the help of a haemocytometer. The infected pods of above genotypes were collected from the field at different intervals and thoroughly washed in running tap water. The pods were cut in 6 mm pieces containing single spot. Fifteen such surface sterilized pieces were incubated in Petri plates in a moist chamber for 48 hrs at room temperature (25°C) with alternating 12 hr light and 12 hr dark periods. Conidia were counted as per method described above.The observations on disease severity were recorded by selecting five plants randomly from each genotype. The disease severity was recorded at 10 days intervals to till maximum disease severity by using 0-6 rating scale as suggested in the Proceedings of All India Co-ordinated. Research Project on Rapeseed-mustard pathology, Planning and Review session-2009-10 given below.

Observations were noted on lower, middle, and upper leaves of randomly selected five plants from each genotype and in each replication.
The per cent disease intensity (PDI) was calculated by employing formula mentioned below:

Table-*1 Evaluation of slow blighting components on the progress of Alternaria blight in mustard under field condition during 2013-2014*

Genotypes	No. of spot/10 cm²		Size of spot (mm)		Sporulation (conidia/ spot)	
	Leaf	Pod	Leaf	Pod	Leaf	Pod
NDWR-05-1	8.63	11.90	4.52	1.97	1290.00	270.87
NDRE-22	12.97	14.83	5.38	2.35	1563.33	322.33
Varuna	16.67	17.45	6.84	2.75	1660.00	571.67
NDR-8501	12.40	14.43	5.33	2.35	1550.00	322.27
NDRE-7	8.43	9.97	4.46	1.18	1148.00	263.20
NDR-2011	13.20	15.37	5.85	2.57	1586.67	343.47
NDRS-2010	15.33	16.33	6.26	2.62	1650.00	355.0
NDRE-4	10.00	12.07	4.67	2.01	1346.67	275.03
PRB-2004-3	11.27	13.10	4.82	2.20	1413.33	302.27
Ashirwad	14.37	15.77	6.06	2.57	1613.33	351.60
JD-6	12.27	14.20	4.94	2.26	1463.33	310.27
NDRE-8213	13.03	15.30	5.60	2.45	1570.00	329.0
NDYR-32	11.73	13.93	4.41	2.21	1420.00	309.27
NDRE—16	10.93	12.60	4.71	2.10	1371.67	298.13
NDYR-8	12.37	14.37	5.05	2.33	1543.33s	316.67
SEm ±	0.32	0.55	0.29	0.22	61.82	15.02
CD at 5%	0.93	1.60	0.85	0.63	179.09	43.51

Table-2 *Evaluation of slow blighting components on the progress of Alternaria blight in mustard under field condition during 2013-2014*

Genotypes	First appearance of disease (DAS)	Per cent disease severity (PDI)		Leaf defoliation (%)	AUDPC on leaves	Yield (kg ha^{-1})
		Leaf	pod			
NDWR-05-1	59	42.67	12.23	42.10	598.60	1516.7
NDRE-22	59	71.67	41.07	56.68	1041.60	1341.7
Varuna	44	73.67	51.17	73.97	1104.65	1090.0
NDR-8501	45	65.17	41.07	55.65	1030.00	1350.0
NDRE-7	60	37.17	12.00	25.28	519.60	1608.3
NDR-2011	50	75.00	43.33	61.58	1082.50	1300.0
NDRS-2010	38	76.13	50.00	64.67	1093.80	1250.0
NDRE-4	56	45.50	13.57	43.20	684.35	1425.0
PRB-2004-3	53	51.37	20.67	47.40	830.25	1350.0
Ashirwad	42	76.07	45.57	63.33	1085.60	1283.0
JD-6	63	55.07	24.90	53.36	947.90	1350.0
NDRE-8213	54	72.50	42.47	58.43	1057.05	1300.0
NDYR-32	51	52.33	22.07	51.54	874.80	1350.0
NDRE—16	60	48.23	17.17	44.67	751.85	1375.0
NDYR-8	62	62.60	26.17	54.42	1008.35	1350.0
SEm ±		0.64	0.47	1.85		43.55
CD at 5%		1.87	1.37	5.36		126.14

PDI=[Sum of total numerical ratings / Total number of leave observed] x [100/Highest grade]

The period from the initial appearance of symptoms and the final incidence of the disease was also considered and the apparent infection rate of the disease spread was calculated according to the following formula [21].

$$\text{Infection rate (r)} = \frac{2.3}{t_2 - t_1} \log_e \frac{x_2 (1-x_1)}{x_1 (1-x_2)}$$

Where,

t_1 = time during first observation

t_2 = time (days) during second observations

$t_2 - t_1$ =time intervals between two observations

x_1=percent disease intensity value in decimal at corresponding t_1 time

x_2 =percent disease intensity value in decimal at corresponding t_2 time

Log e = natural log

The Area under Disease Progress Curve (AUDPC) was calculated by the formula as under:

$$AUDPC = \sum_{i=1}^{n} [(Y_{i+1} + Y_i) \times 0.5][T_{i+1} + T_i]$$

Where

Y_i= *Alternaria blight* severity (%) at the Ist observation

T_i= Time (days) of the Ist observation

n= Total number of observations

For the observations of leaf defoliation, leaves were counted from basal to top. Average was taken based on 5 plants of each genotype in each replication and per cent leaf defoliation was calculated by employing formula mentioned below.

Leaf Defoliation (%) = [Sum of total infected defoliate leaves / Total number of leaves] x 100

Seed yield was recorded in each genotypes separately to determine the differences in yield between each genotype and yield kg ha-1 was calculated.

Result and discussion

The experimental findings of the present investigation entitled "Extent of yield losses and partial resistance to *Alternaria blight* of Indian mustard [*Brassica juncea* (L.) Czern & Coss.]" during 2013-14 have been described in a systematic manner in this chapter. The *Alternaria blight* of mustard caused by *Alternaria brassicae* and *A. brassicicola* is most common disease of eastern Uttar Pradesh. This disease attacks on leaves, stem and pods.

Symptomatology

Brown or grayish spots appear on the leaves. In the initial stage they appeared as black spots but later on enlarged and develop into prominent to round spots with concentric rings. Many spots coalesce, to cover large patches showing blighting and defoliation in severe cases. The spots become linear on the mid-ribs of the leaves were linear and sunken. Circular to linear lesions also developed on stem and pods, which elongated at later stages. Infected pods produced small, discolored and shriveled seeds.

Studies on development of *Alternaria blight* in different genotypes

The use of resistant varieties/ genotypes is considered to be best method of disease control. Therefore, the studies were carried out to find out the sources of resistance against the *Alternaria blight*. A total of fifteen genotypes/varieties of Indian mustard were evaluated for their reaction against the disease under field condition during rabi 2013-14 and the result obtained are presented in [Table-1].

Table-3 *Apparent infection rate of Alternaria blight on leaves and pods of various Indian mustard genotypes during 2013-2014*

Genotypes	Infection rate on leaf (10 days intervals)					Infection rate on pod (10 days intervals)		
	6-12-2013 to 16-12-13	17-12-13 to 26-12-13	27-12-13 to 5-1-14	6-1-14 to 15-01-2014	Mean	16-1-14 to 26-1-14	27-1-14 to 5-2-14	Mean
NDWR-05-1	0.00	0.189	0.146	0.096	0.108	0.267	0.063	0.088
NDRE-22	0.228	0.193	0.262	0.140	0.206	0.270	0.125	0.168
Varuna	0.323	0.208	0.269	0.152	0.238	0.259	0.149	0.191
NDR-8501	0.303	0.181	0.269	0.059	0.201	0.264	0.134	0.167
NDRE-7	0.00	0.173	0.153	0.100	0.107	0.113	0.042	0.084
NDR-2011	0.282	0.192	0.280	0.114	0.217	0.259	0.150	0.178
NDRS-2010	0.327	0.186	0.225	0.191	0.232	0.236	0.163	0.190
NDRE-4	0.00	0.168	0.203	0.077	0.112	0.147	0.075	0.091
PRB-2004-3	0.00	0.188	0.250	0.036	0.119	0.060	0.088	0.106
Ashirwad	0.282	0.192	0.280	0.114	0.217	0.274	0.126	0.182
JD-6	0.00	0.250	0.146	0.103	0.125	0.187	0.162	0.135
NDRE-8213	0.183	0.220	0.279	0.164	0.211	0.265	0.133	0.172
NDYR-32	0.00	0.230	0.154	0.109	0.123	0.272	0.103	0.111
NDRE-16	0.00	0.199	0.220	0.044	0.116	0.144	0.077	0.096
NDYR-8	0.208	0.178	0.269	0.063	0.180	0.316	0.104	0.142

Table-4 *Correlation coefficients (R) among various components of partial resistance of Alternaria blight and yield assessment in mustard genotypes under field conditions*

Disease components and yield	No. of spot	Size of spot	Disease index	Leaf defoliation	*Sporulation*	*AUDPC*	Infection rate	Yield (kg/ha)
No. of spot	1.000	0.949**	0.905**	0.954**	0.100	0.917**	0.878**	-0.952**
size of spots		1.000	0.891**	0.907**	0.057	0.828**	0.917**	-0.877**
Disease index			1.000	0.912**	0.272	0.960**	0.966**	-0.812**
Leaf defoliation				1.000	0.032	0.932**	0.861**	-0.952**
Sporulation					1.000	0.331	0.147	-0.001
AUDPC						1.000	0.892**	-0.860**
Infection rate							1.000	-0.761**
Yield (kg/ha)								1.000

The data presented in [Table-1], showed the number of spots/10 cm^2 on leaves and pods, size of spots (mm) on leaves and pods, conidia per spots on leaves and pods.

First appearance of disease

The disease first appeared on the genotype NDRS-2010 (38 DAS) followed by genotypes Ashirwad (42 DAS), Varuna (44 DAS) and NDR- 8501 (45 DAS). The latest appearance of disease was noted on genotype JD-6 (63 DAS) [Table-2].

Number of spots

The number of spots/ cm^2 on leaves ranged between 8.43 to 16.67 in different genotypes. The minimum number of spots on leaves/10cm^2 was recorded on genotype NDRE-7 (8.43) followed by genotypes NDWR-05-1 (8.63), NDRE-4 (10.0), NDRE-16 (10.93) and PRB-2004-3 (11.27), respectively. The genotypes NDRE-7 (8.43/10 cm^2 leaf spot) and NDWR-05-1 (8.63/10 cm^2 leaf spot) were statistically at par with each other. The genotypes NDRE-16 (10.93/10 cm^2 leaf spot) and PRB-2004-3 (11.27/10 cm^2 leaf spot) were also significantly at par. The significantly high number of spot /10 cm^2 was recorded on genotype Varuna (16.67) followed by NDRS-2010 (15.33) and Ashirwad (14.33), respectively.

The number of spots on pod/10 cm^2 ranged from 9.97 to 17.45 in different genotypes. The least number of spots on pod recorded on genotype NDRE-7 (9.97) followed by NDWR-05-1 (11.90), NDRE-4 (12.07) and NDRE-16 (12.60). The genotypes NDWR-05-1 (11.90), NDRE-4 (12.07), NDRE-16 (12.60) and PRB-2004-3 (13.10) were statistically at par them but were significantly lower than the genotype NDRE-7 (9.97) in respect of spot/10 cm^2 area. The maximum number of spots on pods was recorded on the cultivar Varuna (17.45) followed by NDRS-2010 (16.33), Ashirwad (15.77) and NDR-2011 (15.37) respectively. Later were at par among themselves [Table-1].

Size of spots

The size of spots (mm) on leaves ranged from 4.46 to 6.84 mm in different genotypes. The minimum size of spot on leaf was recorded on genotype NDRE-7 (4.46 mm) followed by NDWR-05-1 (4.52 mm), NDRE-4 (4.67 mm), NDRE-16 (4.71 mm) and PRB-2004-3 (4.82 mm). These genotypes were at par with each other. Varuna showed maximum size of spot (6.84 mm) followed by NDRS-2010 (6.26 mm) and Ashirwad (6.06 mm) respectively, and these were at par with each other. On the pods, size of spots (mm) ranged from 1.18 to 2.75mm.

Minimum size of spots on pod was observed on genotype NDRE-7 (1.18mm) followed by NDWR -05-1 (1.97 mm) and NDRE-4 (2.01mm). The genotypes NDWR-05-1(1.97 mm) and NDRE-4 (2.01 mm) was at par while the NDRE-7 (1.18mm) was significantly differ from other genotypes respectively. The maximum size of spots on pod was recorded on cultivar Varuna (2.75 mm) followed by NDRS-2010 (2.62 mm) and Ashirwad (2.57 mm) respectively, were are no significant difference between them [Table-1].

Sporulation

Similar trend was recorded in case of sporulation or the number of conidia per leaf spot which ranged from 1148.0 to 1660.0 in different genotypes. The minimum number of conidia per leaf spot was recorded in the spot of genotype NDRE-7 (1148.0) followed by NDWR-05-1 (1290.0), NDRE-4 (1346.67) and NDRE-16 (1371.67), respectively. The NDRE-7 (1148.0) was significantly differing from each other but NDWR-05-1 (1290.0) NDRE-4 (1346.67) and NDRE-16 (1371.67) were at par. The maximum number of conidia per leaf spot was recorded on cultivar Varuna (1660.0) followed by NDRS-2010 (1650.0), Ashirwad (1613.0) and NDR-2011 (1586.67). No significant difference was noted in the number of conidia per spot in these genotypes/cultivar. Sporulation on pod ranged from 263.20 to 571.67 conidia per spot. The least number of conidia on pod was recorded on NDRE-7 (263.20) followed by NDWR

05-1 (270.87), NDRE-4 (275.03) and NDRE-16 (298.13), which were at par among themselves. The maximum number of conidia per spot on pods was recorded on cultivar Varuna (571.67) followed by cultivar NDRS-2010 (355.0) and Ashirwad (351.60). The cultivars NDRS-2010 (355.0)and Ashirwad(351.60) were at par while Varuna (571.67) significantly differ from both of them [Table-1].

Per cent disease severity (PDI)

The disease severity (PDI) on leaves ranged from 37.17 to 76.13% in different genotypes/cultivar [Table-2]. Significantly lower disease severity on leaves was recorded on cultivar NDRE-7 (37.1%) followed by NDWR-05-1 (42.62%), NDRE-4 (45.50%) and NDRE-16 (48.23%), respectively.

The maximum disease severity (PDI) on leaves was observed on genotype NDRS-2010 (76.13%) followed by Ashirwad (76.07%), NDR-2011 (75.0%) and Varuna (73.67%). Varuna showed significantly higher disease severity while later were at par with each other [Table-2]. None of the genotypes, under study showed resistance/ moderately resistant reaction,

while four genotypes namely NDRE-7, NDWR-05-1, NDRE-4 and NDRE-16 were recorded susceptible and eleven genotypes/cultivar *viz.,* NDRE-22, Varuna, NDRE-8501, NDR-2011, NDRS-2010, PRB-2004-3, Ashirwad, JD-6, NDRE-8213, NDYR-32 and NDYR-8 were highly susceptible. The disease severity (PDI) on pod also ranged from 12.0 to 51.17% on different genotypes. The minimum disease severity on pod was recorded on cultivar NDRE-7 (12.0%) followed by the NDWR-05-1 (12.23%), NDRE-4 (13.57%) and NDRE-16 (17.17%) respectively. The NDRE-7 (12.0%) NDWR-05-1 (12.23%) and NDRE-4 (13.57%) were at par and NDRE-16(17.17) significantly differs from NDRE-7, NDWR- 05-1, and NDRE-4 [Table-2]. The maximum disease severity on pod was recorded on cultivar Varuna (51.17%) followed by NDRS-2010 (50.0%) which were at par with each other. Four genotypes namely NDRE-7, NDWR-05-1, NDRE-4 and NDRE-16 were noted moderately resistant, four genotypes *viz.,* PRB-2004-3, JD-6, NDYR-32 and NDYR-8 were moderately susceptible, six genotypes (NDRE-22, NDR-8501, NDR-2011, NDR-2010, Ashirwad and NDRE-8213) were susceptible and one cultivar namely Varuna was found highly susceptible in respect of disease severity on pods.

Infection rate

The data presented in [Table-3] showed the infection rate on different genotypes between two dates. On the basis of mean value the infection rate ranged from 0.107 to 0.238 in different genotypes on leaves. The minimum infection rate on leaves was recorded on cultivar NDRE-7 (0.107) followed by NDWR-05-1(0.108), NDRE-4 (0.112), NDRE-16 (0.116) PRB-2004-3 (0.119) and JD-6 (0.125) respectively. The maximum infection rate was recorded on leaves on cultvarVaruna (0.238) followed by NDRS-2010(0.232) and Ashirwad (0.217).The infection rate on pod ranged from 0.084 to 0.191 in different genotypes. The minimum infection rate on pod was recorded on NDRE-7 (0.084) followed by NDWR-05-1 (0.088), NDRE-4 (0.091) and NDRE-16 (0.096), respectively and maximum infection rate on pod was recorded on Varuna (0.191) followed by NDRS-2010 (0.190), Ashiwad (0.182) and NDR-2011 (0.178), respectively [Table-3].

Area Under Disease Progress Curve

A perusal of [Table-2] indicated that the Area Under Disease Progress Curve ranged from 519.60 to 1104.65 in different genotypes. The minimum AUDPC was recorded on NDRE-7 (519.60) followed by NDWR-051 (598.60), NDRE-4 (684.35) and NDRE-16 (751.85) respectively. The maximum AUDPC was observed on cultivar Varuna (1104.65) followed by NDRS-2010 (1093.80), Ashirwad (1085.60), NDR-2011(1082.50) and NDRE-8213(1057.05) respectively.

Leaf defoliation

The leaf defoliation ranged from 25.28 to 73.97 % in different genotypes. The least leaf defoliation was recorded on the cultivar NDRE-7 (25.28%) followed by NDWR-05-1 (42.10%), NDRE-4 (43.20%) and NDRE-16 (44.67%). The NDRE-7 (25.28%) significantly differs from other genotypes in respect of defoliation. However, genotype NDWR-05-1 (42.10 %), NDRE-4 (43.20%) and NDRE-16 (44.67%) were at par with each other. The maximum leaf defoliation was recorded on cultivar Varuna (73.0%) followed by NDRS-2010 (64.67%), Ashirwad (63.33%) and NDR-2011 (61.58%) respectively. The cultivar Varuna also significantly differs from other genotypes/cultivars in respect of higher defoliation. However, the NDRS-2010 (64.67%) Ashirwad (63.33%) and NDR-2011 (61.51%) were at par with each other.

Yield kg/ha

The seed yield was ranged from 1090.0 to 1608.3 kg/ha in different genotypes/cultivar. The maximum seed yield was recorded in cultivar NDRE-7 (1608.3 kg/ha) followed by NDWR-05-1(1516.7 kg/ha) and NDRE-4 (1425.0% kg/ha). The NDRE-7 (1608.3 kg/ha) and NDWR-05-1(1516.7 kg/ha) were at par in respect of seed yield. However, the genotype NDER-4 (1425.0 kg/ha) significantly differ from NDRE-7 and NDWR-0501. The minimum yield was recorded on cultivar Varuna (1090.0kg/ha) followed by NDRS-2010 (1250.0 kg/ha), Ashirwad (1283.0kg/ha) and NDR-2011 (1300.0kg/ha) [Table-2].

Correlation coefficient among different components of partial resistance and yield of mustard genotypes

A perusal of the [Table-4] showed that all the components were highly significant and positively correlation with each other except sporulation which have negative correlation with yield. The highest value of correlation was recorded between disease index and infection rate (R= 0.966) followed by disease index and AUDPC (R= 0.960), where as lowest value of correlation was recorded between leaf defoliation and sporulation (R= 0.032). It means disease index is the most determinant factor for partial resistance that greatly influences the development and progression of epidemic.A perusal of [Table-4] indicate that the number of spot were positively associated with size of spot (0.949), disease index (0.905), leaf Defoliation (0.954), AUDPC (0.917), infection rate (0.878) and negatively associated with yield kg/ha (-0.952). Size of spot is highly significant and positive correlated with disease index (0.891), leaf defoliation (0.907), AUDPC (0.828) infection rate (0.917) and negatively correlated with yield kg/ha (-0.877). Disease index is highly significantly associated with leaf defoliation (0.912), AUDPC (0.960), infection rate (0.966) and negatively correlated with yield kg/ha (-0.812). Leaf defoliation was significantly positively correlated with AUDPC (0.932), infection rate (0.861) and negatively correlated with yield kg/ha (-0.952). Sporulation was positive correlation with AUDPC (0.331), infection rate (0.147) and negatively correlated with yield kg/ha (-0.001). AUDPC was significantly positive associated with infection rate (0.892) and negatively associated with yield kg/ha (-0.860) and infection rate was significantly negatively correlated with yield (-o.761).

Indian mustard (*Brassica juncea* L.) is a major crop of the group Brassicas. Inspite of its higher yield potential, diseases are major constraints, of which Alternaria blight caused by *Alternaria brassicae* (Berk.) Sacc. is one of the more severe yield destabilizing factors. It causes an average yield loss of 35-40 % [6]. In addition to direct loss of yield, the disease adversely affects seed quality by reducing seed size, seed colour and oil content. The resistance identified in different genotypes of Indian mustard is partial or of rate- reducing resistance [7]. Similarly, screening of Mustard Lines against *Alternaria Blight* and Optimization of Screening Time under Cool Humid Conditions of Bihar, India [8]. Infection rate reducing resistance to *Alternaria blight* is a viable strategy in disease management. The utilization of resistant sources in a breeding programme requires detailed investigation in to components of resistance in various blight- resistant genotypes. Overall goal of the present study was to determine the effect of different *Alternaria blight* resistance components on progress of the disease and yield potential of germplasm with known resistance characteristics under field conditions. Brown or grayish spots appeared on the leaves. In the initial stage they appeared as black spots but later on enlarged and develop into prominent to round spots with concentric rings. Many spots coalesced, to cover large patches showing blighting and defoliation in severe cases. Later on, the spots become linear on the mid-ribs of the leaves were linear and sunken. Circular to linear lesions also developed on stem and pods, which elongated at later stages. Infected pods produced small, discolored and shriveled seeds. The symptoms recorded under present investigation are similar as described earliear worker [9-11].

Studies on development of *Alternaria blight* in different genotypes

The use of resistant varieties/genotypes is considered to be best method of disease control. Therefore, the studies were carried out to find out the sources of resistance against the *Alternaria blight*. A total of fifteen genotypes/varieties of Indian mustard were evaluated for their reaction against the disease under field condition during rabi 2013-14. The results indicated that the disease first appeared on the genotype NDRS-2010 (38 DAS) followed by genotypes Ashirwad (42 DAS), Varuna (44 DAS) and NDR- 8501 (45DAS). The latest appearance of disease was noted on JD-6 (63 DAS). The minimum number of spots on leaves and pods/10cm^2 was recorded on cultivar NDRE-7 (8.43, 9.97) followed by genotypes NDWR-05-1 (8.63, 11.90), NDRE-4 (10.0, 12.07), NDRE-16 (10.93, 12.60) and PRB-2004-3 (11.27, 13.10), respectively. Similarly, the NDRE-7 (8.43/10 cm^2 leaf spot) and NDWR-05-1 (8.63/10 cm^2 leaf spot) were statistically at par with each other. Similarly, the genotypes NDRE-16 (10.93/10 cm^2 leaf spot) and PRB-2004-3 (11.27/10 cm^2 leaf spot) were also found at par.

Statistically the significantly high number of spot /10 cm^2 was recorded on the cultivar Varuna (16.67) followed by NDRS-2010 (15.33) and Ashirwad (14.33), respectively. Similar trends were recorded in case of pods also. The maximum number of spots on pod/10 cm^2 was found on Varuna (17.45) followed by NDRS 2010 (16.33), Ashirwad (15.77) and NDR-2011 (15.37) respectively. Later were at par among themselves. The genotypes NDWR-05-1 (11.90), NDRE-4 (12.07), NDRE-16 (12.60) and PRB-2004-3 (13.10) were statistically at par among them but were significantly lower than the genotype NDRE-7 (9.97) in respect of spot/10 cm^2 area. The size of spots (mm) on leaves/pods ranged from 4.46/1.18 to 6.84/2.75 mm in different genotypes/cultivar. The minimum size of spot on leaf /pod was recorded on NDRE-7 (4.46/1.18 mm) followed by NDWR-05-1 (4.52/1.97 mm), NDRE-4 (4.67/2.01 mm). Variation in size of spots on the leaves of this genotypes/cultivar was at par with each other. Varuna showed maximum size of spot on leaves/pods (6.84/2.75mm) followed by NDRS-2010 (6.26/2.62mm) and Ashirwad (6.06/2.57mm) respectively, and these were at par with each other. The NDWR-05-1(1.97mm) and NDRE-4 (2.01mm) were at par while the genotype NDRE-7 (1.18mm) was significantly differs from other genotypes, respectively in respect of spot size on pods. Similar trend was recorded in case of sporulation or the number of conidia on leaf/pod per spot which ranged from 1148.0/263.20 and 1660.0/571.67 in different genotypes. The minimum number of conidia per spot was recorded in the cultivar NDRE-7 (1148.0) followed by NDWR-05-1 (1290.0), NDRE-4 (1346.67) and NDRE-16 (1371.67), respectively. The NDRE-7 (1148.0) was significantly lower than other but genotypes NDWR-05-1 (1290.0) NDRE-4 (1346.67) and NDRE-16 (1371.67) were at par. The maximum number of conidia per leaf/pod spot were recorded on cultivar Varuna (1660.0/571.67) followed by NDRS-2010 (1650.0- 355.0), and Ashirwad (1613.0/351.60), respectively. No significant difference was noted in the number of conidia per spot in these genotypes/cultivars.

The least number of conidia on pod was recorded on NDRE-7 (263.20) followed by NDWR-05-1 (270.87), NDRE-4 (275.03) and NDRE-16 (298.13), which were at par among themes. The disease severity (PDI) on leaves/ pods ranged from 37.17/12.0 and 76.13/51.17% in different genotypes, respectively. Significantly lower disease severity on leaves and pods was recorded on variety NDRE-7 (37.1/12.0%) followed by NDWR-05-1 (42.62/12.23%), NDRE-4 (45.50/13.57%) and NDRE-16 (48.23/17.17%), respectively. Severity of disease on leaves in these genotypes significantly differs from each other. In case of pods the disease severity in NDRE-7 (12.0%) NDWR-05-1 (12.23%) and NDRE-4 (13.57%) were at par statistically, while NDRE-16 (17.17) showed significantly higher disease severity. The maximum disease severity (PDI) on leaves was observed on NDRS-2010 (76.13%) followed by Ashirwad (76.07%), NDR-2011 (75.0%) and Varuna (73.67%). The maximum disease severity on pod was recorded on Varuna (51.17%) followed by NDRS-2010 (50.0%) which were at par with each other. None of the genotypes/cultivar, under study showed resistance/ moderately resistant reaction while four genotypes/cultivar namely NDRE-7, NDWR-05-1, NDRE-4 and NDRE-16 were recorded susceptible and eleven genotypes *viz.,* NDRE-22, Varuna, NDRE-8501, NDR-2011, NDRS-2010, PRB-2004-3, Ashirwad, JD-6, NDRE-8213, NDYR-32 and NDYR-8 were highly susceptible at leaf stage infection. At pod stage reaction, four genotypes namely NDRE-7, NDWR-05-1, NDRE-4 and NDRE-16 were noted moderately resistant, four genotypes *viz.,* PRB-2004-3, JD-6, NDYR-32 and NDYR-8 were moderately susceptible, six genotypes (NDRE-22, NDR-8501, NDR-2011, NDR-2010, Ashirwad and NDRE-8213) were susceptible and one namely Varuna was found highly susceptible. On the basis of mean value, the infection rate (r) ranged from 0.107 and 0.084 to 0.238 and 0.191 in different genotypes on leaves and pods, respectively, the minimum infection rate on leaves was recorded on NDRE-7 (0.107) followed by NDWR-05-1 (0.108), NDRE-4 (0.112), NDRE-16 (0.116) PRB-2004-3 (0.119) and JD-6 (0.125) respectively. Similar trend was recorded in pod infection also. Apparent infection rates among the genotypes highest infection rate were noted on leaves and pods of cultivar Varuna (0.238 and 0.191) followed by genotypes NDRS-2010 (0.232 and 0.190) and Ashirwad (0.217 and 0.182), respectively. Area Under Disease Progress Curve (AUDPC) values were recorded among in different genotypes. AUDPC ranged from 519.60 to 1104.65. The NDRE-7 (519.60) followed by NDWR-051 (598.60), NDRE-4 (684.35) and NDRE-16 (751.85) were slow blighting type. The JD-6 (947.90), NDYR-32 (874.80) and PRB-2004-3 (830.25) were found to be moderately blighting while rest genotypes *viz.,* NDYR-8 (1008.35), NDR-8501 (1030.00), NDRE-22 (1041.60), NDRE-8213 (1057.05), NDR-2011 (1082.50), Ashirwad (1885.60), NDRS-2010 (1093.80) and Varuna (1104) were fast blighting type. The leaf defoliation ranged from 25.28 to 73.97 % in different genotypes. The minimum leaf defoliation was recorded in the cultivar NDRE-7 (25.28%) followed by NDWR-05-1 (42.10%), NDRE-4 (43.20%) and NDRE-16 (44.67%) in comparison to National susceptible check Varuna (73.97%). Defoliation in NDRE-7 (25.28%) was significantly lower than other genotypes/cultivar, however, genotype NDWR-05-1 (42.10 %); NDRE-4 (43.20%) and NDRE-16 (44.67%) were at par with each other. Significantly higher defoliation was recorded in susceptible check Varuna (73.97%). However, the genotypes NDRS-2010 (64.67%) Ashirwad (63.33%) and NDR-2011 (61.51%) were at par with each other.The yield potential of genotypes/cultivar was recorded in kg/ha. The maximum yield was gained in NDRE-7 (1608.3 kg/ha) followed by NDWR-05-1(1516.7 kg/ha) and NDRE-4 (1425.0% kg/ha). The NDRE-7 (1608.3 kg/ha) and NDWR-05-1(1516.7 kg/ha) were at par in respect of seed yield. The cultivar Varuna (1090.0kg/ha) followed by NDRS-2010 (1250.0 kg/ha), Ashirwad (1283.0kg/ha) and NDR-2011 (1300.0kg/ha) were found poor yielder. Correlations showed that all the components were highly significant and positively correlated with each other except sporulation which has negative correlation with yield.

The highest value of correlation was recorded between disease index and infection rate (R= 0.966) followed by disease index and AUDPC (R= 0.960), whereas lowest value of correlation was recorded between leaf defoliation and sporulation (R= 0.032). It means disease index is the most determinant factor for partial resistance that greatly influences the development and progression of epidemic. Partial resistance includes phenomenon such as field resistance [12] and rate reducing resistance [13]. Slow blighting may be defined as reduction in infection of the plant by the blight pathogen, the late appearance of blight symptoms in the life cycle of the host and retorted growth and development of the pathogen. In present investigation, out of fifteen genotypes examined for blight resistance, NDRE-7, NDWR-05-1, NDRE-4 and NDRE-16 exhibited good level of partial resistance. Other eleven genotypes (NDRE-22, Varuna, NDR-8501, NDR-2011, NDRS-2010, PRB-2004-3, Ashirwad, JD-6, NDRE-8213, NDYR-32 and NDYR-8) were highly susceptible based on maximum disease severity, infection rate and Area Under Disease Progress. Various workers evaluated time to time the slow mildewing/ rusting, resistance using different assessment criteria. Wilcoxson (1986) evaluated slow rusting in cereals based on beak severity. Krishna and Mishra (1989) [14] used the infection rates for better assessment of mildew resistance in pea. Kumar and Kolte (2001) [15] also assessed the field resistance to *Alternaria blight* (*Alternaria brassicae*) in nine genotypes of Indian mustard under field condition and reported three genotype *viz*., PR-8988, PR-9024 and Kranti as partial resistance with lower per cent blight cover, apparent infection rate and AUDPC values. In present finding the lower AUDPC values clearly separated the mustard genotypes with high level of partial resistance. AUDPC has been used successfully to evaluate the progress of disease rate on different crops also [16,17].

In the present study, in it is clear that genotypes with high level of partial resistance have good yield potential than susceptible ones. The components of slow blighting being heritable traits could be successfully used in identifying the resistant genotypes. In the present study the resistance against the blight in mustard was largely due to the cumulative effect of less number of spots, reduced size of spots, lower sporulation and leaf defoliation, Which supported the findings of earlier worker of mustard [18-20] as larger lesion developed on susceptible rapeseed- mustard crops than resistant Brassica spp. Different worker from different place have also been reported that defoliation of leaves can be used as a parameter of resistance in *Brassica* spp. In present finding the lower defoliation in genotype NDRE-7 (25%) with higher yield (1608.3kg/ha) support of above views. The genotype NDRE-7, NDWR-05-1, NDRE-4 and NDRE-16 showed good level of partial resistance and these can be effectively used in breeding programme for development of resistant varieties to make integrated disease management programme by reducing the fungicide application frequently. The size of spot, disease index, leaf defoliation, AUDPC and infection rate was found

very important component as it was highly and significantly correlated with most of the component. So, it could be effectively used for the assessment of blighting in rapeseed-mustard.

Conclusions

Indian mustard is one of the major rabi oilseed crop in India. Inspite of improved varieties and large acreage under cultivation, its total production in the country is very low in comparison to other countries of world. Among the various factors responsible for lowering down the yield, foliar diseases, especially, *Alternaria blight* caused by *Alternaria brassicae* and *A. brassicicola* are posing threat to this valuable crop. Studies conducted at the University Student's Instructional Farm of the University. The minimum number of spot/10 cm^2, size of spot (mm), sporulation, disease severity(PDI), leaf defoliation, AUDPC and infection rate and higher yield was obtained in genotype NDRE-7 followed by NDWR-05-1, NDRE-4 and NDRE-16. Significantly maximum number of spot/10cm^2, size of size of spot (mm), sporulation, disease severity (PDI), AUDPC, infection rate and minimum yield was obtained in genotype Varuna followed by NDRS-2010, Ashirwad and NDR-2011.

On the basis of above finding following conclusion were made:

1. The disease first appeared on the genotype NDRS-2010 (38 DAS) followed by Ashirwad (42 DAS), Varuna (44 DAS) and NDR-8501 (45 DAS).
2. The minimum number of leaf spot/10cm^2, size of spot (mm), sporulation, disease severity (PDI), AUDPC, leaf defoliation and maximum yield were recorded in genotypes NDRE-7, NDWR-05-1, NDRE-4, NDRE-16 and PRB-2004-3, respectively.
3. The minimum infection rate was also recorded in the genotypes NDRE-7, NDWR-05-1, NDRE-4, NDRE-16 and PRB- 2004-3, respectively.

Application of research: Study of genotypes with high level of partial resistance have good yield potential than susceptible ones

Research Category: Plant Pathology

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