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Studies on Development of Alternaria Blight on Rapeseed-Mustard and Spray Schedule of Fungicide for its Management

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A B S T R A C T

India is one of the largest rapeseed–mustard growing countries in the world occupying the third position in area and in production after China and Canada with 12% of world's total production. Rapeseed-mustard is the second most important oilseed crop in the country after groundnut and accounts for nearly 30.7% of the total oilseed production in the country. At global level rapeseed–mustard is cultivated on 36.15 m ha with production of 71.09 MT. Alternaria blight caused by *Alternaria brassicae* and *Alternaria brassicicola* has become one of the important diseases of this crop in the country. This disease attacks on stems, leaves and pods. Partial resistance to Alternaria blight was observed in varieties GSL-5, Pusa aditya, Kiran, RH-479, Sheetal, GSL-2, GSL-1 as they are recorded with less number of spots/10 cm^2, small size of spot, less sporulation, less per cent disease severity, less infection rate, less leaf defoliation and higher yield. The last appearance of disease was noted on genotype GSL-5, (53 DAS) followed by Kiran (52 DAS). Significantly lower per cent disease severity on leaves was recorded on cultivar GSL-5 (12.35%) followed by Kiran (14.12%), Pusa aditya (14.16%) and GSL-2 (15.37%), respectively. The minimum infection rate on leaves was recorded on cultivar GSL-5 (0.214) followed by Pusa aditya (0.218).The maximum infection rate was recorded on leaves on cultivar KBS-3 (0.229) followed by PS-66 and T-27 (0.228) respectively. In fungicidal management plot three sprays of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals and three sprays of Nativo 75 EC @ 0.08%, one at DI, second at flowering and third at poding stage showed low per cent disease severity, low infection rate, higher yield and higher avoidable yield loss compared to other treatments. These treatment are proved to be effective compared to other treatments. While control plot showed high per cent disease severity, high infection rate, lower yield and lower avoidable yield loss compared to other treatments. The maximum benefit cost ratio (1:7.72) was obtained with two spray of Nativo 75 EC @ 0.08%, one at FS and second at poding stage followed by three spray of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals (1:7.56). On the basis of above findings it may be concluded that Alternaria blight can causes extent of yield losses in yield of rapeseed-mustard up to 41.16% in eastern Uttar Pradesh. To manage the disease 3 sprays of Nativo @ 0.08 % was most economical and can be recommended to the farmers of blight prove areas.

Introduction

India is one of the largest rapeseed–mustard growing countries in the world occupying the third position in area and in production after China and Canada with 12% of world's total production. Rapeseed-mustard is the second most important oilseed crop in the country after groundnut and accounts for nearly 30.7% of the total oilseed production in the country. At global level rapeseed–mustard is cultivated on 36.15 m ha with production of 71.09 MT.

Rapeseed-mustard oil production increased from 1.94 Million MT from 2014-15 to 2.11 Million MT in 2015-16. European Union (EU) is expected to be the top producer followed by China and Canada in 2015-16. India's share in global production of mustard oil in 2015-16 may be around 9.0 per cent. The US and China were the leading importing countries of mustard oil in the world. India was the 7thlargest importing country in 2014-15. (Anonymous, 2016).

The oil content of rapeseed-mustard varies from 37 to 49%. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout the northern India, in cooking and frying purposes. It is also used in the preparation of hair oils and medicines.

It is used in the manufacture of greases. The oil cake is used as feed and manure. Green stem and leaves are a good source of green fodder for cattle. The oil cakes contain 'sinirgin', that causes palatability problem due to its bitter taste, and glucosinolate that limits use of oil cake as protein supplement. The leaves of young plants are used as green vegetables as they supply sulphur and minerals in the diet. In the tanning industry, mustard oil is used for softening leather.

This lower production is attributable mainly due to biotic and a biotic stresses. Among the biotic stresses, fungal foliar 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 is one of the most severe yield destabilizing factors causing reduction from 35-45% and inflicts very severe losses upto 70% in yellow and brown *sarson* (Kolte *et al.,* 1987 and Kolte., 2002) Research efforts on identification of resistance in mustard to Alternaria blight has got increasing attention over past few years and has been studied for a limited level.

The disease also adversely affects quality by reducing seed size, impairing seed colour and oil content (Kaushik *et al.,* 1984). In the absence of stable resistant varieties, use of fungicides is the only recommendation for the management of Alternaria blight (Kumar., 1997, Prasad *et al.,* 2003, Singh and Singh., 2005[a, b] and Meena *et al.,* 2011) yield loss due to Alternaria blight is meagre in recently released mustard cultivars.

Materials and Methods

The experiment was conducted during Rabi 2016-17 at Student's Instructional Farm of the Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, (U.P) by planting 30 varieties of rapeseed-mustard.

The number of spots was counted per 10 cm^2 leaf area on different leaves. Observations were taken randomly at four places per leaf

lamina on upper surface of leaf, starting from lower most leaf to the uppermost fully developed leaves. This method of counting of spots was followed in all the successive observations. Average number of spots was calculated.

Randomly five plants were selected in each genotype for measuring the spot size. From each plant five leaves were randomly selected on which diameter of randomly selected spots were measured in milli meters (mm).

Average size of leaf spot in each genotype was calculated. Five largest spot per infected siliqua of the selected plants were measured and average was calculated on the basis of fifty spots/genotype. Spots were measured in a sequence starting from lower to upper leaves. Average size of spots on different leaf positions of each genotype was calculated.

The spore production on leaf spots of different genotypes was observed by suspending sporulated lesions in vials containing a mixture of distilled water + lacto phenol (9:1). These lesions were then shaken vigorously and scrapped with the help of camel hair brush. The conidia were counted by examining the spore under the microscopic field with the help of microscope. Then the value is multiplied by 10^3.

Per cent disease severity was calculated by selecting five leaves per plant on five plants from each genotype on a random basis in each replication. The blighting was assessed as per cent leaf area covered. The overall disease scoring was done at 0-9 rating scale on the basis of disease assessment key for Alternaria black spot in rapeseed-mustard. The per cent disease intensity was calculated by using the following formula:

$$\text{Per cent disease intensity (\%)} = \frac{\text{Sum of numerical ratings} \times 100}{\text{Number of leaves examined} \times \text{Maximum grade}}$$

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 (Vander plank, 1963).

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

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

Area under disease progress curve (AUDPC) was calculated on the basis of per cent disease severity for each genotype by using the formula as given below.

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

Where

Y_i= Alternaria blight severity (%) at the I^{st} observation

T_i= Time (days) of the I^{st} observation

n= Total number of observations

Observations on leaf defoliation were taken up to entire growth period of plants. In each observation, leaves were counted from basal to top. Average was taken based on five plants for each genotype in each replication and per cent leaf defoliation was calculated as follows:

$$\text{Leaf defoliation (\%)} = \frac{\text{total number of leaves defoliated}}{\text{total number of leaves on main axis}} \times 100$$

The yields of net area of each plot without border rows were obtained. The obtained yield of each genotype was calculated in q/ha.

Results and Discussion

First appearance of disease

The experiment is conducted during 2016-17 at Student's Instructional Farm of the Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, U.P with following layout.The disease first appeared on the genotype Parwati, T-9 and PT-30 (44 DAS) followed by KOS-1, PS-66, Benoy, Jumka, PT-303, T-27 (45 DAS). The latest appearance of disease was noted on genotype GSL-5, NRCDR-02 (53 DAS).

Number of spots

The number of spots/ cm^2 on leaves ranged between 2.63 to 6.87 in different genotypes. The least number of spots on leaves/10cm^2 was recorded on genotype Kiran (2.63) which was at par with Giriraj (3.07), Jhumka (3.47), Pusa aditya (3.65) and NRCHB-101 (3.67) but it significantly differed from others. The maximum number of spot /10 cm^2 was recorded on genotype Parwati (6.87) followed by PT-303, PC-5 and T-27 (6.67) and KOS-1 & Benoy (6.47), respectively. The number of spots on pod/10 cm^2 ranged from 2.74 to 16.74 in different genotypes. The minimum number of spots on pod recorded on genotype PC-5 (2.74) which was at par with Kiran (3.14), GSL-5, Sheetal (4.14) and GSL-1 (4.54) but it significantly differed from others. The maximum number of spots on pods was recorded on the cultivar Patan sarson-66 (16.74) which significantly differed from all others.

Size of spots

The size of spots (mm) on leaves ranged from 3.05 to 9.26 mm in different genotypes. The minimum size of spot on leaf was recorded on genotype Pusa aditya (3.05 mm) which was at par with TMLC-2 (3.54 mm), GSL-5 (4.23 mm), GSL-2 (4.47 mm) and GSL-1 (4.52 mm) but significantly differed from others. Patan sarson-66 showed maximum size of spot (9.26 mm) which significantly differed from all others followed by Pusa mustard-27 (8.70), KBS-3 (8.68) and Pusa mustard-26 (8.66 mm) respectively. Giriraj, PT-303 and T-27 have similar size of spot (8.46 mm). On the pods, size of spots (mm) ranged from 1.22 to 7.00 mm. Smallest size of spots on pod was observed on genotype GSL-5 (1.22 mm) which was at par with PC-5 (1.27 mm) and Kiran (1.47mm) and significantly differed from others. The largest size of spots on pod was recorded on cultivar Kranti (7.00 mm) which was significantly differed from all others followed by Parwati (6.67 mm), Pusa gold-45 (6.07 mm) respectively. There was no significant difference between them.

Sporulation

Similar trend was recorded in case of sporulation or the number of conidia per leaf spot which ranged from 1230 to 5900 in different genotypes. Number of conidia per spot on leaf was lowest in the genotype GSL-5 (1230) which was at par with Pusa aditya (1630), Kiran (1660) and GSL-1 (1800) and significantly differed from others. The highest number of conidia per leaf spot was recorded on cultivar Jhumka (5900) which significantly differed from others followed by KBS-3 (5430), Kranti (5230) and Patan sarson-66 (5200).

Sporulation on pod ranged from 120 to 670 conidia per spot. The least number of conidia per spot on pod was recorded on Kiran (120) which was at par with GSL-5 (130), RH-406 & Sheetal (150), GSL-1 & GSL-2 (160) and significantly differed from others. The highest number of conidia per spot on pods was recorded on cultivar Jhumka (670) which significantly differed from all others followed by cultivar KBS-3 (580) and Patan sarson-66 & kranti (570) respectively.

Table.1 Evaluation of slow blighting components on the progress of Alternaria blight on rapeseed-mustard under field condition during 2016-17

S.No.	Genotypes	Appearance of disease (DAS)	No. of spots/10 cm^2		Size of spot (mm)		Sporulation (conidia/spot)	
			Leaf	Pod	Leaf	Pod	Leaf	Pod
1.	GSL-5	53	4.60	4.14	4.23	1.22	1230	130
2.	KOS-1	45	6.47	5.74	6.40	1.77	3230	200
3.	PC-5	50	6.67	2.74	6.66	1.27	2760	170
4.	RH-406	49	5.47	4.94	8.26	3.47	2160	150
5.	TMLC-2	46	5.50	13.34	3.54	3.45	5030	430
6.	Pusa Aditya	50	3.65	5.34	3.05	4.27	1630	170
7.	Parwati	44	6.87	6.14	7.86	6.67	4400	200
8.	Pusa mustard-25	47	6.07	10.34	6.86	4.07	4230	250
9.	Anuradha	49	4.47	6.94	7.86	4.87	3460	210
10.	Giriraj	50	3.07	12.94	8.46	4.63	2300	190
11.	T-9	44	5.47	6.34	7.46	4.37	4900	280
12.	Patan sarson-66	45	6.27	16.74	9.26	4.47	5200	570
13.	Pusa mustard-27	48	5.47	7.14	8.70	4.67	3930	410
14.	Pusa gold-45	47	6.27	5.94	6.66	6.07	4330	460
15.	Benoy	45	6.47	7.94	7.46	4.05	4000	460
16.	GSL-1	52	5.47	4.54	4.52	2.08	1800	160
17.	Jhumka	45	3.47	4.74	8.16	5.27	5900	670
18.	PT-303	45	6.67	9.34	8.46	4.03	3330	360
19.	KBS-3	47	4.67	7.34	8.68	3.87	5430	580
20.	PT-30	44	4.87	4.54	6.06	3.97	5000	440
21.	GSL-2	52	4.58	6.94	4.47	1.87	1800	160
22.	Sheetal	50	4.20	4.14	5.25	2.89	1960	150
23.	Kiran	52	2.63	3.14	4.68	1.47	1660	120
24.	NRCDR-02	53	5.57	4.94	5.45	3.02	3130	250
25.	RH-479	49	4.87	7.14	5.86	2.70	2800	190
26.	NRCHB-101	50	3.67	5.94	4.53	2.86	3060	270
27.	T-27	45	6.67	7.54	8.46	2.67	4860	390
28.	Pusa mustard-24	48	4.07	5.74	7.86	3.27	4960	470
29.	Kranti	47	4.87	5.94	7.46	7.00	5230	570
30.	Pusa mustard-26	46	5.07	5.54	8.66	3.30	4760	480
	C.D at 5%		**1.26**	**1.43**	**1.37**	**0.78**	**112.00**	**34.80**
	SEm±		**0.21**	**0.56**	**0.32**	**0.27**	**25.00**	**3.00**
	C.V		**5.94**	**5.93**	**5.64**	**4.43**	**6.43**	**6.67**

Table.2 Per cent disease severity (%) of Alternaria blight on leaves and pods of rapeseed-mustard genotypes under field conditions during 2016-2017

S. No.	Genotypes	Per cent disease severity (PDI) (%) on leaves days after sowing (DAS)					Mean	Per cent disease severity (PDI) (%) on pods days after sowing (DAS)					Mean
		55	65	75	85	95		80	90	100	110	120	
1.	GSL-5	2.00	5.16	11.77	18.13	24.72	12.35	2.33	2.38	5.48	12.57	18.53	8.25
2.	KOS-1	5.16	21.94	34.46	47.76	58.79	33.62	2.53	12.60	26.58	50.57	70.63	32.58
3.	PC-5	5.20	12.33	29.85	44.64	56.36	29.67	2.63	18.51	32.48	58.67	76.73	37.80
4.	RH-406	4.80	10.66	26.95	37.99	51.47	26.37	3.43	10.62	29.38	43.47	60.93	29.56
5.	TMLC-2	4.60	31.33	53.93	65.66	86.10	48.32	6.63	22.51	37.68	50.77	80.63	39.64
6.	Pusa aditya	2.23	7.22	12.29	20.07	28.99	14.16	2.26	2.41	4.48	12.67	16.83	7.73
7.	Parwati	5.30	17.02	36.33	54.64	73.77	37.41	3.63	15.72	40.58	63.47	78.53	40.38
8.	Pusa mustard-25	5.20	23.33	44.44	53.37	68.03	38.87	2.63	5.70	13.38	32.57	56.73	22.20
9	Anuradha	4.86	16.25	39.02	52.57	78.03	38.14	3.53	18.73	30.48	63.87	75.93	38.50
10.	Giriraj	4.93	13.33	22.40	39.26	51.11	26.20	2.14	2.35	3.68	10.87	20.63	7.93
11.	T-9	5.06	23.33	40.75	52.90	76.77	39.76	3.73	16.60	34.48	50.67	78.83	36.86
12.	Patan sarson-66	8.16	29.30	42.91	55.25	74.32	41.98	5.63	18.72	38.58	70.57	86.03	43.90
13.	Pusa mustard-27	3.20	12.33	33.07	44.46	57.49	30.11	2.43	12.60	30.38	45.47	61.93	30.56
14.	Pusa gold-45	5.56	19.32	42.45	48.69	73.58	37.92	6.63	20.50	40.48	55.77	78.63	40.40
15.	Benoy	7.80	12.33	30.66	43.47	69.35	32.72	5.73	18.72	37.68	60.77	76.83	39.94
16.	GSL-1	4.86	8.23	15.25	22.16	29.00	15.90	2.15	2.35	5.58	13.57	22.93	9.31
17.	Jhumka	4.83	16.41	33.46	65.66	72.37	38.54	4.53	20.51	39.68	63.47	79.03	41.44
18.	PT-303	5.20	22.88	34.39	49.10	74.76	37.26	3.53	15.60	31.48	52.77	79.63	36.60
19.	KBS-3	10.16	22.95	51.14	64.33	70.59	43.83	2.63	16.80	33.68	48.57	63.83	33.10
20.	PT-30	5.36	24.21	38.86	53.90	83.93	41.25	4.63	15.61	33.48	56.47	83.73	38.78
21.	GSL-2	2.63	6.69	14.31	23.70	29.55	15.37	2.27	2.34	4.78	10.67	21.63	8.33
22.	Sheetal	3.33	7.17	16.03	27.00	32.93	17.29	2.18	2.38	5.68	9.67	23.83	8.74
23.	Kiran	3.43	7.66	13.50	21.64	24.40	14.12	2.14	2.35	8.18	12.77	25.93	10.27
24.	NRCDR-02	3.26	13.55	25.33	45.66	57.15	28.99	2.63	12.51	28.48	50.57	61.73	31.18
25.	RH-479	4.20	11.90	25.94	32.33	54.46	25.76	2.53	16.72	22.58	45.47	58.63	29.18
26.	NRCHB-101	2.80	14.82	28.54	43.66	53.45	28.65	2.43	15.62	25.38	46.57	61.73	30.34
27.	T-27	5.76	29.55	38.40	52.75	63.26	37.94	7.53	22.50	32.68	50.67	65.53	35.78
28.	Pusa mustard-24	4.63	17.05	39.11	46.64	56.84	32.85	2.73	10.49	30.48	53.47	67.63	32.96
29.	Kranti	4.43	14.98	34.43	48.01	59.32	32.23	2.63	12.71	28.68	50.77	63.63	31.68
30.	Pusa mustard-26	5.70	14.66	39.01	45.04	57.96	32.47	2.53	9.50	25.58	47.57	60.73	29.18
	Mean	4.82	16.26	31.63	44.01	58.29	31.00	3.42	12.55	25.40	43.19	59.28	28.77
	C.D at 5%	**1.18**	**1.74**	**3.42**	**3.66**	**5.43**		**1.23**	**1.92**	**2.12**	**3.69**	**4.77**	
	SEm±	**0.33**	**1.31**	**2.08**	**2.45**	**3.28**		**0.39**	**1.38**	**2.29**	**3.47**	**4.15**	
	C.V	**5.88**	**4.50**	**6.43**	**5.38**	**6.69**		**9.13**	**6.42**	**1.44**	**5.59**	**5.81**	

Per cent disease severity (PDI):

On mean basis the disease severity (PDI) on leaves ranged from 12.35 to 48.32% in different genotypes/cultivar. Lower per cent disease severity on leaves was recorded on cultivar GSL-5 (12.35%) followed by Kiran (14.12%), Pusa aditya (14.16%) and GSL-2 (15.37%), respectively.

The maximum disease severity (PDI) on leaves was observed on genotype TMLC-2 (48.32%) followed by KBS-3 (43.83%), PS-66 (41.98%) and PT-30 (41.25%).

Genotypes TMLC-2, Pusa mustard-25, Anuradha, T-9, Patan sarson-66, Jhumka, KBS-3, PT-30, T-27 were recorded susceptible and genotypes GSL-5, Pusa aditya, GSL-1, GSL-2, Sheetal, Kiran were recorded resistant. Per cent disease index increased significantly with time from 65-85 DAS.

The per cent disease severity (PDI) on pod also ranged from 7.73 to 43.90% on different genotypes. The minimum per cent disease severity on pod was recorded on cultivar Pusa aditya (7.73%) followed by the Giriraj (7.93%), GSL-5 (8.25%) and GSL-2 (8.33%), respectively.

The maximum disease severity on pod was recorded on cultivar PS-66 (43.90%) which significantly differed from others followed by Jhumka (41.44%), Pusa gold (40.40) and parwati (40.38).

On the basis of mean none of the genotypes were found highly resistant or resistant. Out of 30 genotypes seven genotypes (GSL-5, Pusa aditya, Kiran, RH-479, Sheetal, GSL-2, GSL-1) were found moderately resistant and 23 genotypes (KOS-1, PC-5, RH-406, TMLC-2, Parwati, Pusa mustard-25, Anuradha, Giriraj, T-9, Patan sarson-66, Pusa mustard-27, Pusa gold-45, Benoy, Jhumka, PT-303, KBS-3, PT-30, NRCDR-02, NRCHB-101, T-27, Pusa mustard-24, Kranti, Pusa mustard-26 as susceptible.

Infection rate

The infection rate on different genotypes between two dates. On the basis of mean value the infection rate on leaves ranged from 0.05 to 0.12 in different genotypes on leaves. The minimum infection rate on leaves was recorded on cultivar GSL-1 (0.05) which was at par with Sheetal (0.06) and significantly differed from others. The maximum infection rate was recorded on leaves on cultivar TMLC-2 (0.12).

The infection rate on pod ranged from 0.09 to 0.13 in different genotypes. The minimum infection rate on pod was recorded on RH-406 (0.09) but significantly differed from others and maximum infection rate on pod was recorded on PC-5 which significantly differed from all others followed by TMLC-2.

Area under disease progress curve

A perusal of Table-6 indicated that the Area Under Disease Progress Curve (AUDPC) on leaves ranged from 486.70 to 1962.70 in different genotypes. The minimum AUDPC was recorded on GSL-5 (486.70) followed by Pusa aditya (551.90), Kiran (567.15) and GSL-2 (607.90), respectively. The maximum AUDPC was observed on cultivar TMLC-2 (1962.70) followed by KBS-3 (1787.95), PS-66 (1687.00), PT-30 (1616.15) and T-9 (1578.95), respectively.

Area under disease progress curve on pods ranged from 282.85 to 1423.80. Minimum AUDPC was recorded in Giriraj (282.85) followed by Pusa aditya (291.05), GSL-2 (297.40), Sheetal (307.35) and Maximum AUDPC was recorded in PS-66 (1737.00), followed by Jhumka (1654.40).

Table.3 Evaluation of slow blighting components on the progression of Alternaria blight on rapeseed-mustard under field condition during 2016-2017

S.No.	Genotypes	Leaf defoliation	AUDPC		Yield (kg ha^{-1})	Test weight (g)
			Leaf	Pod		
1.	GSL-5	33.55	486.70	308.60	2944.85	3.38
2.	KOS-1	33.87	1361.35	1263.30	1133.74	2.79
3.	PC-5	37.36	1176.00	1493.40	1222.63	2.96
4.	RH-406	43.07	1037.35	1156.50	1500.40	4.59
5.	TMLC-2	37.99	1962.70	1545.90	815.95	3.22
6.	Pusa aditya	33.86	551.90	291.05	2667.05	3.18
7.	Parwati	55.05	1475.25	1608.50	1200.09	3.33
8.	Pusa mustard-25	43.80	1577.55	813.30	3200.40	3.78
9.	Anuradha	61.51	1492.85	1528.10	1655.96	2.90
10.	Giriraj	50.22	1030.10	282.85	1622.63	4.90
11.	T-9	49.19	1578.95	1430.30	1889.29	4.82
12.	Patan sarson-66	32.03	1687.00	1737.00	955.96	3.23
13.	Pusa mustard-27	38.68	1202.05	1206.30	2089.29	3.36
14.	Pusa gold-45	51.28	1500.30	1593.80	1222.63	5.36
15.	Benoy	52.99	1280.35	1584.50	1133.74	2.74
16.	GSL-1	38.05	625.70	340.40	2733.74	3.40
17.	Jhumka	57.36	1541.30	1654.40	1044.85	3.75
18.	PT-303	53.34	1463.50	1414.30	1067.07	3.08
19.	KBS-3	51.64	1787.95	1322.80	1155.96	3.54
20.	PT-30	55.75	1616.15	1497.40	933.74	3.29
21.	GSL-2	36.47	607.90	297.40	1433.74	3.76
22.	Sheetal	37.88	683.30	307.35	2044.85	3.96
23.	Kiran	29.15	567.15	373.35	1944.85	3.72
24.	NRCDR-02	49.15	1147.45	1237.40	2278.18	3.72

25.	RH-479	38.05	995.00	1153.50	2333.74	4.74
26.	NRCHB-101	50.22	1151.45	1196.50	2222.63	4.16
27.	T-27	35.10	1552.10	1423.80	733.78	3.80
28.	Pusa mustard-24	38.79	1335.35	1296.20	1944.85	3.48
29.	Kranti	34.86	1292.95	1251.55	1933.74	5.16
30.	Pusa mustard-26	46.05	1305.40	1142.80	1722.63	4.36
	C.D at 5%	**3.40**			**221.69**	
	SEm±	**0.02**			**121.17**	
	C.V	**5.05**			**8.06**	

Table.4 Correlation coefficients (r) among various components of partial resistance of Alternaria blight and yield assessment in rapeseed-mustard varieties under field conditions during 2016-2017

Disease components and yield	No. of spots	Size of spot	Disease index	Leaf defoliation	Sporulation	AUDPC	Infection rate	Yield
No. of spots	1.000	0.313	0.452*	0.050	0.282	0.446*	0.365	-0.339
Size of spot		1.000	0.557**	0.372	0.577**	0.552**	0.635**	-0.434*
Disease index			1.000	0.491**	0.882**	0.998**	0.702**	-0.598**
Leaf defoliation				1.000	0.367	0.464*	0.363	-0.271
Sporulation					1.000	0.888**	0.617**	-0.505**
AUDPC						1.000	0.698**	-0.593**
Infection rate							1.000	-0.566**
Yield								1.000

*Significant at 5% ** Significant at 1%

Leaf defoliation

The leaf defoliation ranged from 29.15 to 61.51% in different genotypes. The least leaf defoliation was recorded on the cultivar Kiran (29.15%) which was at par with PS-66 (32.03%) and significantly differed from others. The maximum leaf defoliation was recorded on cultivar Anuradha (61.51%) which significantly differed from all others followed by Jhumka (57.36%).

Yield kg/ha

The yield was ranged from 733.78 to 3200.40 kg/ha in different genotypes/cultivar. The maximum seed yield was recorded in cultivar Pusa mustard-25 (3200.40 kg/ha) which significantly differed from all others followed by GSL-5 (2944.85 kg/ha) and GSL-1 (2733.74% kg/ha) the GSL-5 (2944.85 kg/ha) and GSL-1 (2733.74 kg/ha) were at par in respect of yield.

Whereas, Pusa mustard (3200.40 kg/ha) significantly superior with other genotypes. The minimum yield was recorded on cultivar T-27 (733.38 kg/ha) which was at par with TMLC-2 (815.95 kg/ha), PT-30 (933.74kg/ha) and PS-66 (955.96kg/ha) and significantly differed from others.

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

A perusal of the Table-7 showed that all the components were highly significant and positively correlation with each other. The highest value of correlation was recorded between disease index and AUDPC (r= 0.958) followed by sporulation and AUDPC (r= 0.888), whereas lowest value of correlation was recorded between number of spot and sporulation (r= 0.282). 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-7 indicate that the number of spot were positively associated with size of spot (0.313), disease index (0.452), leaf defoliation (0.050), sporulation (0.282), AUDPC (0.446) infection rate (0.365), and negatively associated with yield kg/ha (-0.339). Size of spot is positively correlated with disease index (0.557), leaf defoliation (0.372), sporulation (0.577), AUDPC (0.552), infection rate (0.635) and negatively correlated with yield kg/ha (-0.434). Disease index is significantly associated with leaf defoliation (0.491), AUDPC (0.998), sporulation (0.882), infection rate (0.707) and negatively correlated with yield kg/ha (-0.598).

Leaf defoliation was significantly positively correlated with sporulaton (0.367), AUDPC (0.464), infection rate (0.363) and negatively correlated with yield kg/ha (-0.271). Sporulation was positive correlation with AUDPC (0.888), infection rate (0.617) and negatively correlated with yield kg/ha (-0.505). AUDPC was positively associated with infection rate (0.698) and negatively correlated with yield kg/ha (-0.593) and infection rate was positively correlated with yield (-0.566).

Spray schedule of fungicide

The experiment was conducted at Student's Instructional Farm of the University during 2016-17 by using cultivar NDR-8501 and data were recorded.

Per cent disease severity (PDI)

The results revealed that all the treatments significantly reduced the disease severity in comparison to unsprayed plot (Table-8). The mean disease severity (PDI) on leaves ranged

from 6.40 to 47.48 %. The minimum disease severity of 6.40% was recorded with three sprays of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals followed by three sprays of Nativo 75 EC @ 0.08%, one at DI, second at flowering and third at poding stage (6.85%), two sprays of Nativo 75 EC @ 0.08%, at flowering stage and second at poding stage (18.91%) and two sprays of Nativo 75 EC @ 0.08%, one at disease initiation and second at poding stage (21.07%). The maximum disease severity (PDI) was recorded in unsprayed plot (47.48%)

In case of pod infection the mean disease severity (PDI) ranged from 5.53 to 55.24 %. The minimum disease severity (PDI) was recorded on pods with three sprays of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals (5.53%), followed by three sprays of Nativo 75 EC @ 0.08%, one at DI, second at flowering and third at poding stage (7.26%), two sprays of Nativo 75 EC @ 0.08%, one at disease initiation and second at flowering stage (20.66), two sprays of Nativo 75 EC 0.08%, at flowering stage and second at poding stage (21.74) and maximum disease severity (PDI) was found in Unsprayed plot (56.24 %).

Infection rate

Spray of fungicide (Nativo 75 EC) was started after first appearance of disease. The progress of disease was recorded at 10 days interval. The perusal of The Table-8 showed that infection rate of the disease on leaves was maximum in between 80 to 90 DAS. After that infection rate gradually decreased in all the treatments.

The minimum infection rate on mean basis on leaves was recorded in three spray of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals (0.216) followed by three spray of Nativo 75 EC @ 0.08%, one at DI, 2nd FS and 3rd at poding stage, single spray of Nativo 75 EC @ 0.08% at disease initiation (DI) (0.052) (0.222), two spray of Nativo 75 EC @ 0.08%, one at FS and second at poding stage (0.223), two spray of Nativo 75 EC @ 0.08%, one at DI and second at FS (0.024) respectively. Maximum infection rate was recorded in Control (Water spray) (0.229).

Infection rate on pod mean ranged from 0.217-0.229. Minimum infection rate was recorded in three spray of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals (0.217) and maximum disease severity was recorded in control plot (0.229).

Area under disease progress curve

The observation on AUDPC Table-8 indicated that all the treatments reduced the AUDPC in comparison to unsprayed plot. The minimum AUDPC on leaves was recorded with three sprays of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals (263.80) followed by three sprays of Nativo 75 EC @ 0.08%, one at DI, second at FS and third at poding stage (274.85), two sprays of Nativo 75 EC @ 0.08%, one at FS and second at poding stage (764.05), two sprays of Nativo 75 EC @ 0.08%, one at DI and second at PS (868.10), respectively. Diseases severity increased with decreased number of spraying of fungicide Nativo. Maximum AUDPC was recorded in unsprayed plots (1930.35).

It is clear from the Table-8 that AUDPC on pod ranged from 82.95 to 843.65. maximum AUDPC was recorded in control plot (843.65) and minimum AUDPC was recorded in three sprays of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals (82.95) followed by three sprays of Nativo 75 EC @ 0.08%, one at DI, second at FS and third at poding stage (108.90)

Table.5 Effect of fungicide (Nativo 75 EC) under different spray schedule on the per cent disease severity (PDI) and infection rate of Alternaria blight on mustard during 2016-2017

S. No.	Treatments	Per cent disease severity (PDI)										AUDPC	
		On leaves days after sowing (DAS)						On pod days after sowing (DAS)					
		60	70	80	90	100	Mean	100	110	120	Mean	Leaf	Pod
1.	T_1	2.66	13.24	40.39	52.00	68.13	35.28	19.22	44.81	57.24	40.42	1410.25	606.35
2.	T_2	9.09	16.52	23.39	25.33	54.35	25.73	38.13	45.66	49.91	44.56	969.60	668.50
3.	T_3	2.87	16.52	22.39	28.33	39.42	21.90	16.94	21.14	23.91	20.66	883.85	309.95
4.	T_4	2.94	11.52	27.39	29.35	34.16	21.07	29.21	34.6	38.24	34.01	868.10	510.25
5.	T_5	9.59	16.52	19.39	22.32	26.76	18.91	17.83	22.81	24.58	21.74	764.05	326.10
6.	T_6	2.00	5.90	6.97	7.88	9.26	6.40	2.84	5.84	7.91	5.53	263.80	82.95
7.	T_7	2.78	4.90	7.74	8.05	10.81	6.85	3.86	6.34	11.58	7.26	274.85	108.90
8.	T_8	9.09	35.52	50.39	54.33	66.33	43.13	45.72	50.81	53.61	50.04	1779.50	750.70
9.	T_9	10.09	17.15	51.40	63.51	78.66	47.48	53.01	55.81	59.91	56.24	1930.35	843.65
	Mean	5.67	33.75	27.71	32.34	43.09	25.19	25.19	31.64	36.32	31.05		
	C.D at 5%	**1.57**	**3.01**	**3.42**	**3.31**	**4.09**		**2.12**	**3.52**	**3.32**			
	SEm±	**1.34**	**3.60**	**5.50**	**6.67**	**8.42**		**5.88**	**5.91**	**6.16**			
	C.V	**7.39**	**7.40**	**6.43**	**5.69**	**5.86**		**4.31**	**6.43**	**5.61**			

T_1-Single spray of Nativo 75 EC @ 0.08% at disease initiation (DI), T_2-Single spray of Nativo 75 EC @ 0.08% at flowering stage (FS) T_3-Two spray of Nativo 75 EC @ 0.08%, one at DI and second at FS, T_4-Two spray of Nativo 75EC @ 0.08%, one at DI and second at poding stage (PS), T_5-Two spray of Nativo 75 EC @ 0.08%, one at FS and second at poding stage, T_6-Three spray of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals, T_7-Three spray of Nativo 75 EC @ 0.08%, one at DI, 2^{nd} FS and 3^{rd} at poding stage, T_8-Single spray of Nativo 75 EC @ 0.08% at poding stage, T_9 -Control (Water spray)

Table.6 Effect of fungicide (Nativo 75 EC) under different spray schedule on test weight (1000 seed weight) and yield of mustard 2016-17

S. No.	Treatment	Test weight (gm)	Avoidable test weight loss (%)	Seed yield	
				Kg/ha	Avoidable loss
1.	T_1-Single spray of Nativo 75 EC @ 0.08% at disease initiation (DI)	4.16	3.6	1644.85	12.15
2.	T_2-Single spray of Nativo 75 EC @ 0.08% at flowering stage (FS)	4.28	6.3	1755.96	17.71
3.	T_3-Two spray of Nativo 75 EC @ 0.08%, one at DI and second at FS	4.96	19.15	1922.63	24.85
4.	T_4-Two spray of Nativo 75EC @ 0.08% , one at DI and second at poding stage (PS)	4.68	14.31	2067.07	30.10
5.	T_5-Two spray of Nativo 75 EC @ 0.08%, one at FS and second at poding stage	5.02	20.11	2133.74	32.28
6.	T_6-Three spray of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals	5.5	27.09	2455.96	41.16
7.	T_7-Three spray of Nativo 75 EC @ 0.08%, one at DI, 2^{nd} FS and 3^{rd} at poding stage	5.45	26.42	2411.51	40.08
8.	T_8-Single spray of Nativo 75 EC @ 0.08% at poding stage	4.25	5.64	1567.07	7.79
9.	T_9 -Control (Water spray)	4.01	3.6	1444.85	
	C.D at 5%			**361.83**	
	SEm±			**211.20**	
	C.V			**9.51**	

Yield Kg/ ha

All the treatments increased the yield in comparison to unsprayed plot (Table-9). The seed yield ranged from 1444.85 kg/ha to 2455.96 kg/ha in different treatments.

The maximum seed yield was recorded in three sprays of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals (2455.96 kg/ha) which significantly differed from all others followed by three sprays of Nativo 75 EC @ 0.08%, one at DI, second at FS and third at poding stage (2411.51 kg/ha) and minimum seed yield was recorded in unsprayed plot (1444.85 kg/ha).

No significant difference was noted among treatment unsprayed plot and One spray of Nativo @ 0.08 %. However three spray of nativo @ 0.08 % first at DI, second at FS and third at PS and three sprays of Nativo @ 0.08 % first at DI, second and third at 15 days intervals were at par with each other.

Avoidable yield loss

The yield loss was avoided from 7.79 to 41.16 per cent in different treatments. The maximum yield loss was avoided with three spray of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals (41.16 %) followed by three spray of Nativo 75 EC @ 0.08%, one at DI, 2nd FS and 3rd at poding stage (40.08 %), two spray of Nativo 75 EC @ 0.08%, one at FS and second at poding stage (32.28 %), two spray of Nativo 75EC @ 0.08% , one at DI and second at poding stage (30.10 %), two spray of Nativo 75 EC @ 0.08%, one at DI and second at FS (24.85 %), single spray of Nativo 75 EC @ 0.08% at flowering stage (17.71 %), single spray of Nativo 75 EC @ 0.08% at disease initiation (12.15 %) and single spray of Nativo 75 EC @ 0.08% at poding stage (7.79), respectively.

Test weight (1000 seed weight in g)

The test weight (1000 seed weight in g) ranged between 4.01 to 5.50 gm. The maximum test weight recorded in three spray of Nativo 75EC @ 0.08% , one at DI and second at FS and third at 15 days interval (5.50), followed by three spray of Nativo 75 EC @ 0.08%, one at DI, 2nd FS and 3rd at poding stage (5.45), two spray of Nativo 75 EC @ 0.08%, one at FS and second at poding stage (5.02), two spray of Nativo 75 EC @ 0.08%, one at DI and second at FS (4.96) and minimum test weight was recorded in control plot (4.01).

Avoidable test weight loss (%)

The avoidable test weight loss ranged from 1.83 to 27.21. minimum Avoidable test weight loss was observed in single spray of Nativo 75 EC @ 0.08% at flowering stage (1.83) followed by three spray of Nativo 75EC @ 0.08% , one at DI and second at FS and third at 15 days interval (3.60), single spray of Nativo 75 EC @ 0.08% at poding stage (6.14) respectively. Maximum Avoidable test weight loss was observed in control plot (12.29).

Benefit cost ratio

The data presented in table-10 indicated that on the basis of economics the maximum benefit cost ratio (1:7.72) was obtained with two spray of Nativo 75 EC @ 0.08%, one at FS and second at poding stage followed by three spray of Nativo 75 EC @ 0.08%, one at DI, second and third at 15 days intervals, three spray of Nativo 75 EC @ 0.08%, one at DI, 2nd FS and 3rd at poding stage (1:7.22), single spray of Nativo 75 EC @ 0.08% at flowering stage and two spray of Nativo 75EC @ 0.08% , one at DI and second at poding stage (1:6.97), two spray of Nativo 75 EC @ 0.08%, one at DI and second at FS

(1:5.35) and single spray of Nativo 75 EC @ 0.08% at disease initiation (1:4.48), respectively. Minimum benefit cost ratio of 1:2.74 was found with single spray of Nativo 75 EC @ 0.08% at poding stage.

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