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OPTIMIZATION OF ECO-FRIENDLY CHEMICALS ON ALTERNARIA BLIGHT DISEASE PROGRESSION AND YIELD COMPONENTS OF MUSTARD

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ABSTRACT

The significantly minimum average size of spot was observed in KCl at 1.0% (2.02 mm) followed by $Na_2B_4O_7.10H_2O$ at 0.75% (2.09 mm) and $CaSO_4$ at 0.5% (2.12 mm) in comparison to check (2.83 mm).The minimum average number of leaf spots/25 mm^2 area was found in $CaSO_4$ at 1.5% (5.79) followed by $CaSO_4$ at 0.5% (5.97) in comparison to check (9.29). The minimum average apparent infection rate on leaf was recorded in $CaSO_4$ at 0.5% (0.616) followed by $CaSO_4$ at 1.5% (0.633) and $Na_2B_4O_7.10H_2O$ at 0.75% (0.638). The minimum AUDPC was observed in $Na_2B_4O_7.10H_2O$ at 0.75% (59.6 mm^2) followed by $CaSO_4$ at 0.5% (61.25 mm^2) and KCl at 1.0% (61.55 mm^2). The minimum apparent infection rate on pod was observed in treatment $Na_2B_4O_7.10H_2O$ at 0.75% in the observation intervals 80-90 DAS and 100-110 DAS (0.517 and 0.754, respectively) while in the observation interval 90-100 DAS, minimum apparent infection rate was found in $Na_2B_4O_7.10H_2O$ at 0.25% (0.667). $CaSO_4$ at 1.0% showed maximum seed yield/plant (8.54 g) and total yield/ha (1.91 t/ha) in comparison to check. This study suggested that $CaSO_4$ providing the maximum reduction of alternaria blight disease and enhanced the maximum yield of mustard.

INTRODUCTION

Indian mustard (*Brassica juncea* L.) is one of the major oilseed crops that alone contributes about 80% of the total rapeseed-mustard production in India. Among the oilseed crops, rapeseed-mustard produced 6.6 million tonnes from 5.9 million ha area in India with an average yield of 1185 kg/ha in 2011-12 (GOI, 2013). Alternaria blight of rapeseed-mustard is the most common and destructive disease of oilseed brassicas and caused by an imperfect fungus, *Alternaria brassicae* (Berk.) Sacc., *A. brassicicola* (Schw.) Wilts., *A. raphani* Groves and Skolko and *A. alternata* (Fr.) Keissler. This disease infected seedling stage on cotyledons and in the adult stage on leaves, petioles, stem, inflorescence, siliquae and seeds (Kumar *et al.*, 2014). Alternaria blight may be responsible for 10-70 per cent average yield losses in rapeseed-mustard depending upon prevailing weather and disease situations (Kolte *et al.*, 1987; Ram and Chauhan, 1998). The severity of infection of this disease depends upon the environmental factors *i.e.* abundant moisture or frequent rains followed by warm and dry weather. A range of temperature 23 to 29°C was found to be most appropriate for disease development (Ansari *et al.*, 1988; Chattopadhyay *et al.*, 2005; Biswas, 2013). This disease is also adversely affects seed quality by reducing seed size, imparting seed colours and oil content (Kaushik *et al.*, 1983).

Alternaria blight disease can be managed by the use of different fungicides (Verma and Saharan, 1994; Khan *et al.*, 2007; Sultana *et al.*, 2009). The control of plant diseases using fungicides raises serious concerns about food safety, environmental quality and fungicides resistance to pathogen which have forced to search all possible alternative for safe disease management.

A number nutrient is important for growth and development of plants and also important factors in disease control (Agrios, 2005). All the essential nutrients can affect disease severity (Huber and Graham, 1999). A particular nutrient can increase or decrease the disease severity depending upon disease, age of plant and environment (Marschner, 1995; Graham and Webb 1991; Huber, 1980). The disease progression is important for understanding plant-pathogen interaction where differences in level of resistance are usually less distinct. Disease starts at a very low level and gradually increasing over time in the growth period of plants (Chattopadhyay*et al.*, 2005; Biswas, 2013). There was lot of study done on the development of alternaria blight disease and their interaction of environmental conditions but available information pertaining to optimization of eco-friendly chemicals on alternaria disease progression and their effect on yield of mustard are very few. The present investigation has been carried out with a view to test the different eco-friendly chemicals on disease progression of alternaria blight and yield components of mustard.

MATERIALS AND METHODS

The present investigations were carried out to study the optimization of five eco-friendly chemicals *viz.*, calcium sulphate ($CaSO_4$), potassium chloride (KCl), potassium sulphate (K_2SO_4), zinc sulphate ($ZnSO_4$), and borax ($Na_2B_4O_7$'"$10H_2O$) on disease progression against alternaria blight and yield attributes of mustard variety varuna at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (India) which is geographically situated at 29°N latitude and 79.73°E longitude, at an altitude of 243.80 meter above sea level and has humid and sub-tropical (*Tarai*) climate. All the chemicals were used in three different concentrations. The field experiment was conducted in a randomized block design (RBD) with three replications. The plot size for each treatment was 3 × 2 m^2 with row-to-row distance 40 cm and plant-to-plant distance 10-15 cm. Recommended dose of fertilizers of NPK (100 : 40 : 40) kg ha^{-1} were applied in the form of urea, single superphosphate and muriate of potash, respectively. The total amount of phosphorus, potash and ½ of the nitrogen were applied as basal and the remaining nitrogen was applied at two split doses after first and second irrigation *i.e.* 30 and 60 days after sowing (DAS), respectively. Two sprays of respective concentrations of each chemical were sprayed during the entire growth period of plants with an atomizer. First spray of respective chemicals was given on the leaves of 25 days old plants and the second spray was given after onset of disease.

Size of spot was recorded by randomly selected five spots/leaf and was measured in mm including yellow halo, chlorotic area with necrotic brown area in the centre at 10 days interval (Kumar *et al.*, 2014). The numbers of spots on leaf per 25 mm^2 leaf area were also recorded at 10 days interval with the help of a glass slide (Kumar *et al.*, 2014). Observations were taken on five leaves and average size of spots and number spots per 25 mm^2 area was then calculated. Apparent infection rates(r) were calculated on leaf and pod on the basis of disease index at 10 days interval and calculated by using formula given by Vanderplank (1963).

$$r = \frac{2.3}{t_2 - t_1} \log_{10} \frac{x_2(1-x_1)}{x_1(1-x_2)}$$

Where,

r = apparent infection rate

x_1 = disease index at time t_1

x_2 = disease index at time t_2

t_1 = time of initial disease rating (x_1)

t_2 = time of second disease rating (x_2)

The area under disease progress curve (AUDPC) was calculated for comparative study of disease progress in different treatments by following Wilcoxson *et al.* (1975).Area under disease progress curve was plotted by plotting time interval on x-axis and size of spot (mm) on Y-axis in respect of different treatments.

$$\text{A-value} = \sum_{i-1}^{K} \frac{1}{2}(S_i + S_{i-1})\ d$$

Where,

S_i = Disease severity at the end of week i

K = Number of successive evaluation of disease

d = Interval between two evaluations.

The plant growth and yield components *viz.* plant height, average length of main raceme, average length of siliqua, thousand seed weight, seed yield /plant and seed yield/hectare were recorded. Five randomly selected plants per treatment were taken for observation. All data were statistically analyzed using an analysis of variance (ANOVA) to determine the least significant difference ($P < 0.05$).

RESULTS AND DISCUSSION

The size of leaf spot was highly significant among the treatments, observation intervals and their interactions (Table 1). The significantly maximum percent reduction of average size of spot was observed in KCl at 1.0% (28.62 per cent) followed by $Na_2B_4O_7.10H_2O$ at 0.75% (26.14 per cent), $CaSO_4$ at 0.5% (25.08 per cent) and $CaSO_4$ at 1.0% (20.49 per cent) in comparison to check. The significantly higher average size of spot was recorded in KCl at 1.5% (2.82 mm) followed by $ZnSO_4$ at 0.5% (2.65 mm) in comparison to all the treatments. The maximum and minimum size of spot after 90 DAS were found in K_2SO_4 at 1.0% (5.80 mm) and $Na_2B_4O_7.10H_2O$ at 0.75% (4.50 mm), respectively.

All the treatments showed reduction in number of leaf spots/ 25 mm^2 area but the significantly maximum percent reduction was found in $CaSO_4$ at 1.5% (37.67 per cent) followed by $CaSO_4$ at 0.5% (35.73 per cent) and Borax at 0.75% and K_2SO_4 at 1.0% (30.57 per cent both) in comparison to check. The maximum number of leaf spots/25 mm^2 area was found in case of check (9.29) and K_2SO_4 at 0.5% (8.00). The number of leaf spots/25 mm^2 area was observed to be highly significant among the treatments and observation intervals. The interactions between the treatments and observation intervals were also found significant (Table 2).

The apparent infection rate progressively increased between 60-70, 70-80 and 80-90 DAS on leaf (Table 3). The minimum average apparent infection rate was recorded in $CaSO_4$ at 0.5% (r = 0.616) followed by $CaSO_4$ at 1.5% (r = 0.633) and $Na_2B_4O_7.10H_2O$ at 0.75% (r = 0.638). The maximum apparent infection rate was observed in check followed by $ZnSO_4$ at 0.25% in all the three interval.

The area under disease progress curve was measured (mm^2) for different treatments on leaf. The minimum AUDPC was observed in $Na_2B_4O_7.10H_2O$ at 0.75% (59.6 mm^2) followed by $CaSO_4$ at 0.5% (61.25 mm^2) and KCl at 1.0% (61.55 mm^2) (Fig. 1). Among the three treatments of KCl, the maximum AUDPC was measured at 1.5% (83.50 mm^2) (Table 4).

The apparent infection rate progressively increased between 80-90, 90-100 and 100-110 DAS on pod (Table 5). The average apparent infection rate on pod revealed that the maximum and minimum apparent infection rate was found in

Table 1: Effect of eco-friendly chemicals on size of leaf spot of alternaria blight on leaf at different stages of growth of mustard.

Treatment	Concentration (%)	Size of leaf spot (mm)				Mean	Reduction over check (%)
		60 DAS	70 DAS	80 DAS	90 DAS		
	0.5	0.00	1.03	2.73	4.73	2.12	25.08
$CaSO_4$	1.0	0.12	1.30	2.93	4.66	2.25	20.49
	1.5	0.27	1.50	2.66	4.73	2.29	19.08
	0.5	0.13	1.60	2.90	4.93	2.39	15.54
KCl	1.0	0.73	1.20	2.36	4.46	2.02	28.62
	1.5	0.24	1.50	3.90	5.66	2.82	0.35
	0.5	0.28	1.33	2.46	5.13	2.30	18.72
K_2SO_4	1.0	0.27	1.20	3.16	5.80	2.61	7.77
	1.5	0.23	1.33	3.00	5.00	2.39	15.54
	0.25	0.16	1.20	3.06	5.00	2.35	16.96
$ZnSO_4$	0.50	0.20	1.26	3.53	5.60	2.65	6.36
	0.75	0.13	1.46	3.53	5.40	2.63	7.06
	0.25	0.70	1.00	2.66	5.53	2.31	18.37
$Na_2B_4O_7.10H_2O$	0.50	0.28	1.53	3.00	4.93	2.43	14.13
	0.75	0.22	1.10	2.50	4.50	2.09	26.14
T check	–	0.52	1.60	4.00	5.20	2.83	–
Mean		0.20	1.32	3.02	5.08		
C.D. at 5%							
Treatment						0.23	
Interval						0.11	
Interaction						0.46	

Table 2: Effect of eco-friendly chemicals on number of alternaria leaf spots at different stages of growth of mustard

Treatment	Concentration (%)	Number of leaf spots/25 mm^2 area				Mean	Reduction over check (%)
		60 DAS	70 DAS	80 DAS	90 DAS		
	0.5	0.00	2.63	7.86	13.40	5.97	35.73
$CaSO_4$	1.0	0.40	2.16	7.33	15.60	6.37	31.43
	1.5	0.53	3.00	7.50	12.13	5.79	37.67
	0.5	0.40	3.60	8.03	16.33	7.09	23.68
KCl	1.0	0.20	2.70	10.86	17.60	7.84	15.60
	1.5	0.56	3.46	10.36	16.73	7.78	16.25
	0.5	0.66	3.36	11.16	16.80	8.00	13.88
K_2SO_4	1.0	0.53	3.43	7.16	14.66	6.45	30.57
	1.5	0.33	3.80	9.20	16.13	7.36	20.77
	0.25	0.26	2.36	9.33	17.40	7.34	20.99
$ZnSO_4$	0.50	0.70	2.73	8.03	15.06	6.63	28.63
	0.75	0.46	3.16	9.40	14.53	6.89	28.83
	0.25	0.16	2.26	9.20	17.73	7.34	20.99
$Na_2B_4O_7.10H_2O$	0.50	0.89	2.60	8.90	18.13	7.63	17.86
	0.75	0.73	3.46	7.10	14.53	6.45	30.57
T check	-	1.80	5.43	12.90	17.06	9.29	–
Mean		0.54	3.13	9.02	15.86		
C.D. at 5%							
Treatment						0.43	
Interval						0.21	
Interaction						0.87	

check (r = 0.751) and Borax at 0.75% (r = 0.646) respectively. The minimum apparent infection rate was observed in treatment $Na_2B_4O_7.10H_2O$ at 0.75% in the observation intervals 80-90 DAS and 100-110 DAS (r = 0.517 and 0.754, respectively) while in the observation interval 90-100 DAS, minimum apparent infection rate was found in $Na_2B_4O_7.10H_2O$ at 0.25% (r = 0.667).

There was no significant effect on plant height due to non-conventional chemicals (Table 6). But $CaSO_4$ at 1.0% resulted more plantheight (2.07 m) followed by $Na_2B_4O_7.10H_2O$ at 0.25% (2.06 m) over check (1.89 m).All the treatments showed non-significant effect on average length of main raceme except KCl at 1.0% (84.42 cm) over check (73.42 cm) (Table 6). None of the non-conventional chemicals showed significant effect on average length of siliqua but the maximum average length of siliqua recorded in $ZnSO_4$ at 0.5% (5.41 cm). There was non-significant effect on 1000-seed weight due to effect of non-conventional chemicals. However, $Na_2B_4O_7.10H_2O$ at 0.75% showed slight increase in the seed weight in comparison to check (Table 6).

All the treatments of calcium sulphate ($CaSO_4$) and potassium sulphate (K_2SO_4) showed significant difference among themselves. The maximum seed yield/plant was recorded in case of $CaSO_4$ at 1.0% (8.54 g) over check (5.47 g).The total

Table 3: Effect of eco-friendly chemicals on apparent* infection rate (r) of alternaria blight on leaf at different stages of growth of mustard

Treatment	Concentration (%)	Apparent infection rate (r) 60-70 DAS	70-80 DAS	80-90 DAS	Mean
	0.5	0.387	0.700	0.761	0.616
$CaSO_4$	1.0	0.470	0.760	0.802	0.677
	1.5	0.449	0.688	0.763	0.633
	0.5	0.427	0.742	0.813	0.660
KCl	1.0	0.472	0.723	0.822	0.672
	1.5	0.469	0.742	0.820	0.677
	0.5	0.430	0.715	0.825	0.656
K_2SO_4	1.0	0.431	0.719	0.823	0.657
	1.5	0.451	0.750	0.832	0.677
	0.25	0.488	0.788	0.838	0.704
$ZnSO_4$	0.50	0.431	0.780	0.830	0.680
	0.75	0.463	0.766	0.822	0.685
	0.25	0.393	0.744	0.788	0.641
$Na_2B_4O_7.10H_2O$	0.50	0.387	0.717	0.822	0.642
	0.75	0.470	0.680	0.766	0.638
T check	–	0.542	0.793	0.848	0.727

* Apparent infection rate computed on the basis of disease index.

Table 4: Effect of eco-friendly chemicals on AUDPC of alternaria blight of mustard on leaf at different stages of growth of mustard.

Treatment	Concentration (%)	AUDPC (A) (mm^2)
	0.5	61.25
$CaSO_4$	1.0	66.20
	1.5	66.60
	0.5	70.30
KCl	1.0	61.55
	1.5	83.50
	0.5	64.95
K_2SO_4	1.0	73.95
	1.5	69.95
	0.25	68.40
$ZnSO_4$	0.50	76.90
	0.75	77.55
	0.25	67.75
$Na_2B_4O_7.10H_2O$	0.50	71.35
	0.75	59.60
T check	–	84.6

AUDPC = area under disease progress curve.

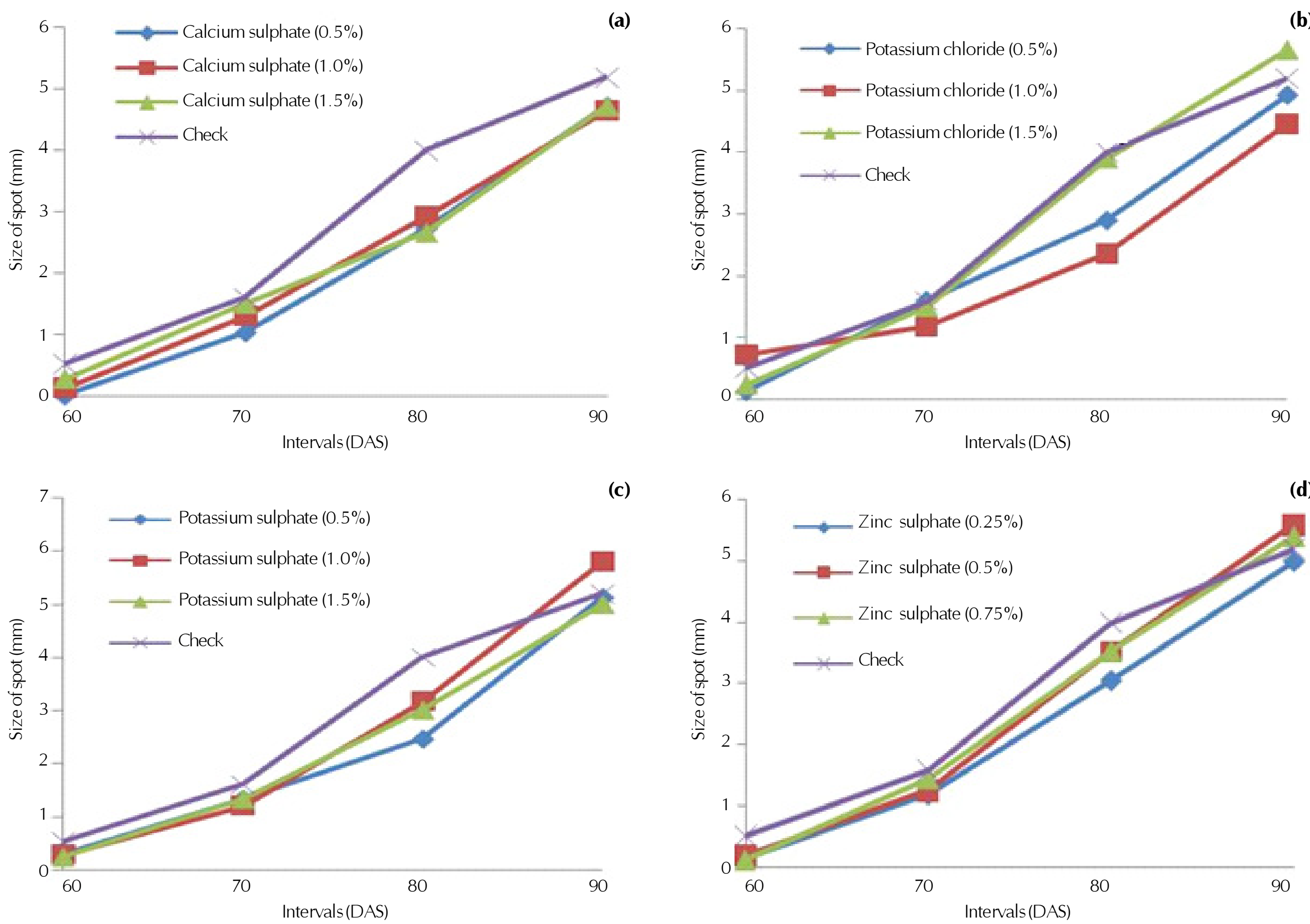
seed yield/ha increased in all the treatments over check except K_2SO_4 at 1.0%. The maximum seed yield/ha was observed in treatment $CaSO_4$ at 1.0% (1.91 t/ha) followed by treatment $Na_2B_4O_7.10H_2O$ at 0.75% (1.64 t/ha) and $CaSO_4$ at 1.5% (1.59 t/ha). Among the treatments of calcium sulphate ($CaSO_4$), maximum seed yield/ha recorded in case of $CaSO_4$ at 1.0% (1.91 t/ha) followed by $CaSO_4$ at 1.5% (1.59 kg/ha) and $CaSO_4$ at 0.5% (1.56 t/ha) (Table 6).

The present study showed the importance of eco-friendly chemicals on alternaria blight disease progression and yield components of mustard. The effect of nutrients on disease resistance may be attributed to (i) effects on plant growth that can influence the microclimate in a crop and thereby affect infection and sporulation of the pathogen, (ii) effects on cell walls and tissues, as well as biochemical composition of the host (iii) influence the rate of growth of the host, which may enable plants to escape infection in their susceptible stages (Dordas, 2008). A number of macronutrients and micronutrients identified that are not recognized as essential

Table 5: Effect of eco-friendly chemicals on apparent* infection rate (r) of alternaria blight on pod at different stages of growth of mustard

Treatment	Concentration (%)	Apparent infection rate (r) 80-90 DAS	90-100 DAS	100-110 DAS	Mean
	0.5	0.587	0.756	0.792	0.711
$CaSO_4$	1.0	0.539	0.726	0.776	0.680
	1.5	0.595	0.747	0.803	0.715
	0.5	0.539	0.726	0.783	0.682
KCl	1.0	0.595	0.744	0.801	0.713
	1.5	0.570	0.677	0.766	0.671
	0.5	0.632	0.689	0.761	0.694
K_2SO_4	1.0	0.604	0.728	0.803	0.711
	1.5	0.563	0.675	0.762	0.666
	0.25	0.568	0.751	0.807	0.708
$ZnSO_4$	0.50	0.540	0.701	0.797	0.679
	0.75	0.590	0.671	0.797	0.686
	0.25	0.556	0.667	0.773	0.665
$Na_2B_4O_7.10H_2O$	0.50	0.598	0.698	0.785	0.693
	0.75	0.517	0.669	0.754	0.646
T check	–	0.652	0.767	0.835	0.751

*Apparent infection rate computed on the basis of disease index.



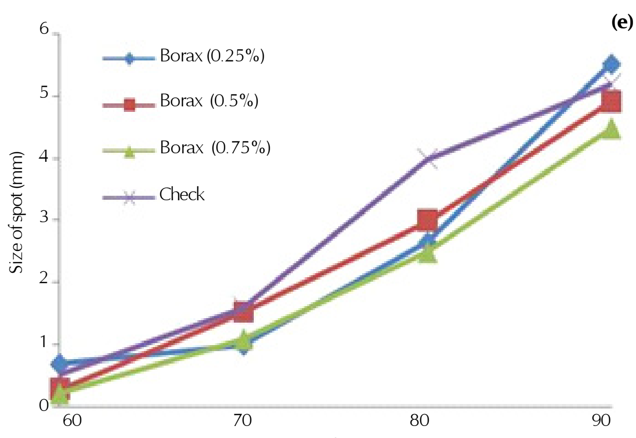


Figure 1: Effect of eco-friendly chemicals on AUDPC of alternaria blight in relation to size of spot (mm) on leaf in mustard

for growth and developments of plants but involved in specific signaling pathways which may lead to the development of resistance in plants against the pathogens. (Graham, 1983; Agrios, 2005). It can control or reduce plant diseases by direct toxicity to the pathogens or by promoting induced systemic resistance. Brassica plant species has a relatively high nutrient requirement and most soils on which the crop is grown are deficient in one or more nutrients foroptimum seed yield and oil and protein content (Grant and Bailey, 1993).

Meena *et al.* (2011) supported the present work that calcium sulphate, borax and zinc sulphate were found effective against alternaria blight of Indian mustard. A basal application of ZnSO4, borex and sulphur followed by spray of *Pseudomonas fluorescens* were found most effective to reduce the disease intensity (19.06 and 20.7%) on leaves and disease intensity (5.83 and 15.1%) on pod respectively (Singh *et al.*, 2014). Calcium is a critical part of the cell wall that produces strong structural rigidity by forming cross-links within the pectin polysaccharide matrix and maintained the structural integrity of stems that hold flowers and fruit, as well as the quality of the fruit produced (Huber and Arny, 1985; Marschner, 1995). Fungal and bacterial pathogenic infection is also reduced with increased calcium uptake by plants. calcium applications reduced diseases caused by several pathogens (Volpin &Elad, 1991; Conway *et al.*, 1992; Yamazaki and Hoshina, 1995; Biggs *et al.*, 1997). It confers resistance against *Pythium*, *Sclerotinia*, *Botrytis* and *Fusarium* (Graham, 1983). Foliar spray of calcium compounds sequesters the organic acids at the site of infection (Verma and Saharan, 1994). Induced resistance against alternaria blight of rapeseed-mustard was revealed by soil or foliar application of calcium compounds (Tewari, 1991; Kumar *et al.*, 2014).

Boron was found to reduce the severity of many diseases because of the function to strengthen cell wall structure, plant membranes and plant metabolism. The diseases caused by

Table 6: Effect of eco-friendly chemicals on growth and yield contributing components of mustard

Treatment	Concentration (%)	Plant growth and yield components					
		Plant height (m)	Average length of main raceme (cm)	Average length of siliqua (cm)	1000-seed weight	Seed yield /plant (g)	Total seed yield/ha (t)
	0.5	1.96	77.30	4.97	4.20	4.38	1.56
$CaSO_4$	1.0	2.07	71.31	4.82	4.18	8.54	1.91
	1.5	1.94	81.30	5.22	4.42	6.95	1.59
	0.5	1.98	73.12	5.02	4.04	4.66	1.49
KCl	1.0	1.94	84.42	5.21	4.09	4.89	1.51
	1.5	2.00	77.67	5.30	4.16	4.97	1.50
	0.5	2.04	71.88	5.40	4.32	5.49	1.33
K_2SO_4	1.0	2.05	72.60	5.20	4.26	7.28	1.53
	1.5	2.11	66.67	5.24	4.14	6.52	1.44
	0.25	2.15	79.86	5.08	4.19	4.96	1.39
$ZnSO_4$	0.50	1.92	82.31	5.41	4.29	5.31	1.33
	0.75	1.98	65.53	5.34	3.69	6.21	1.51
	0.25	2.06	71.05	5.11	4.10	4.87	1.42
$Na_2B_4O_7.10H_2O$	0.50	1.97	75.26	5.20	4.17	6.41	1.38
	0.75	1.91	77.42	5.20	4.51	5.50	1.64
T check	–	1.89	73.42	5.30	4.49	5.47	1.35
C.D. at 5%		NS	10.27	NS	NS	0.96	0.21

Plasmodiophora brassicae (Woron.) in crucifers, *Fusarium solani* (Mart.) (Sacc.) in bean, *Verticillium albo-atrum* (Reinke and Berth) in tomato and cotton, tobacco mosaic virus in bean, tomato yellow leaf curl virus in tomato, (Graham and Webb, 1991) and *Blumeria graminis* (D.C.) (Speer) in wheat (Marschner, 1995) were reduced by the application of Boron. The foliar spray of boric acid (0.53%) gave 20-64 per cent disease control of Alternaria blight of mustard (Vishwanath, 1987). Zinc has also reported to reduce disease because of the toxicity on the pathogen directly and not through the plant's metabolism (Graham and Webb, 1991). Zn to the soil reduced infections by *Fusarium graminearum* (Schwabe) and root rot diseases, *e.g.* caused by *Gaeumannomyces. graminis* (Sacc.) in wheat (Graham and Webb, 1991; Grewal *et al.*,1996).

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REFERENCES

Agrios, G. N. 2005. Plant pathology, 5th Edn., *Elsevier Academic Publishers, California,* USA, p. 922.

Biggs, A. R., El-Kholi, M. M., El-Neshawy, S. and Nickerson, R. 1997. Effects of calcium salts on growth, polygalacturonase activity, and infection of peach fruit by *Monilinia fructicola*. *Plant Disease,* **81(4):** 399-403.

Biswas, M. K. 2013. Influence of environmental factors on the development of alternaria blight of mustard caused by *Alternaria 'brassicae, The Ecoscan.* **4(Spl. Issue)**: 139-144

Chattopadhyay, C., Agrawal, R., Kumar, A., Bhar, L. M., Meena, P. D., Meena, R. L., Khan, S. A., Chattopadhyay, A. K., Awasthi, R. P., Singh, S. N., Chakravarthy, N. V. K., Kumar, A., Singh, R. B., Bhunia, C. K. 2005. Epidemiology and forecasting of Alternaria blight of oilseed Brassica in India-a case study. *J. Plant Dis. Prot.* **112(4):** 351-365.

Conway, W. S., Sams, C. E., Mcguire, R. G. and Kelman, A. 1992. Calcium treatment of apples and potatoes to reduce post-harvest decay. *Plant Disease.* **76(4):** 329-334.

Dordas, C. 2008. Role of nutrients in controlling plant diseases in sustainable agriculture. A review. *Agron. Sustain. Dev.* **28:** 33-46.

GOI 2013. Agriculture Statistics at a Glance 2013. Directorate of Economics and Statistics, Dept. Agrilculture and Cooperation, Ministry of Agriculture, GOI,New Delhi. pp. 90-127.

Graham, R. D. 1983. Effect of nutrient stress on susceptibility of plants to disease with particular reference to the trace elements. *Adv. Bot. Res.* **10:** 221-276.

Graham D. R. and Webb M. J. 1991. Micronutrients and disease resistance and tolerance in plants, in: Mortvedt, J. J., Cox, F. R., Shuman, L. M., Welch R. M.(Eds.), Micronutrients in Agriculture, 2nd ed. Soil Science Society of America, Inc. *Madison, Wisconsin, USA*, pp. 329-370.

Grant, C. A. and Bailey, L. D. 1993. Fertility management in Canola production. *Can. J. Pl. Sci.* **73:** 651-670.

Grewal, H. S., Graham, R. D., Rengel, Z. 1996. Genotypic variation in zinc efficiency and resistance to crown rot disease (*Fusarium graminearum* Schw. Group 1) in wheat, *Plant and Soil.* **186:** 219-226.

Huber, D. M. 1980. The role of mineral nutrition in defense. In Plant Disease, An Advanced Treatise (Vol. 5), How Plants Defend Themselves, in: Horsfall, J. G., Cowling, E. B. (Eds.), Academic Press, New York. pp. 381-406.

Huber, D. M. and Arny, D. C. 1985. Interactions of potassium with plant disease, In: Munson, R.D. ed. Potassium in agriculture. Madison, Wisconsin, *American Society of Agronomy*. pp. 667-688.

Huber, D. M. and Graham, R. D. 1999. The role of nutrition in crop resistance and tolerance to disease, in: Rengel, Z. (Ed.), Mineral nutrition of crops fundamental mechanisms and implications, Food Product Press, New York, pp. 205-226.

Kaushik, C. D., Kaushik, J. C. and Saharan, G. S. 1983. Field evaluation of fungicides for the control of Alternaria leaf blight of *Brassica juncea*.

Indian J. Mycol. Pl. Pathol. **13:** 262-264.

Khan, M. M., Khan, R. U. and Mohiddin, F. A. 2007. Studies on the cost-effective management of alternaria blight of rapeseed-mustard (*Brassica spp.*) *Phytopathologia Mediterranea*. **46(2):** 201-206.

Kolte, S. J., Awasthi, R. P. and Vishwanath 1987. Assessment of yield losses due to Alternaria blight in rapeseed and mustard. *Indian Phytopathol.* **40(2):** 209-211.

Kumar, A., Kumar, S., Kumar, R., Chand, G. and Kolte, S. J. 2014. Fungicidal effect of some non-conventional chemicals for management of alternaria blight disease of mustard. *J. Appl. and Nat. Sci.* **6(2):** 913-919.

Marschner, H. 1986. Relationship between mineral nutrition and plant diseases and pests. In: Mineral Nutrition of Higher Plants. *Academic Press,* New York, pp. 369-390.

Marschner H. 1995. Mineral Nutrition of Higher Plants, 2^{nd} ed., *Academic Press,* London, p. 889.

Meena, P. D., Chattopadhyay, C., Kumar, A., Awasthi, R. P., Singh, R., Kaur, S., Thomas, L., Goyal, P. and Chand, P. 2011. Comparative study on the effect of chemicals on alternaria blight in Indian mustard - A multi-location study in India. *J. Environmental Biology*. **32(3):** 375-379.

Ram, R. S. and Chauhan, V. B. 1998. Assessment of yield losses due to Alternaria leaf spot in various cultivars of mustard and rapeseed. *J. Mycopathol. Res.* **36(2):** 109-111.

Singh, D., Prasad, R. and Yadav, S. P. 2014. Characterization of *Alternaria brassicae* causing alternaria blight of rapeseed- mustard (*Brassicae juncea* L.) and it's management. *The Bioscan*. **9(3):** 1207-1212.

Sultana, N. A., Khan, M. A. H., Islam, M. N. and Nahar, K. 2009. Evaluation of appropriate time for the application of rovral against alternaria blight incidence and yield of mustard. *International J. Sustainable Agriculture*. **1(1):** 20-23.

Tewari, J. P. 1991. Structural and biochemical bases of black spot disease of crucifers. *Adv. Struct. Biol.* **1:** 325-349.

Vanderplank, J. E. 1963. Plant Diseases: Epidemics and Control. *Academic Press,* New York, London, p. 349.

Verma, R. P. and Saharan, G. S. 1994. Monograph on Alternaria diseases of crucifers. Saskatoon Research Station, Technical Bulletin, p. 162.

Vishwanath 1987. Studies on some fungicides and micronutrients in the control of three important disease of Toria (*Brassica campestris* var. toria). *Thesis, M.Sc. Ag. (Plant Pathology), G.B. Pant Univ. of Agric. & Tech., Pantnagar,* p. 235.

Volpin, H. and Elad, Y. 1991. Influence of calcium nutrition on susceptibility of rose flowers to botrytis blight. *Phytopath.* **81(11):** 1390-1394.

Wilcoxson, R. D., Skovmand, B. and Atif, A. H. 1975. Evaluation of wheat cultivars for their ability to retard development of stem rust. *Annals of Applied Biology*. **80(3):** 275-281.

Yamazaki, H. and Hoshina, T. 1995. Calcium nutrition affects resistance of tomato seedlings to bacterial wilt. *Horticulture Science,* **30:** 91-93.