

**STUDIES ON EPIDEMIOLOGY AND MANAGEMENT  
OF ALTERNARIA BLIGHT OF MUSTARD**

**Thesis**

**Submitted to the**



**Banda University of Agriculture & Technology, Banda-210001  
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**By**

**PRADIP KUMAR**

**(Id. No. 1021)**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS**

**FOR THE DEGREE OF**

**MASTER OF SCIENCE (AGRICULTURE)**

**IN**

**PLANT PATHOLOGY**

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# BANDA UNIVERSITY OF AGRICULTURE & TECHNOLOGY, BANDA

**Dr. H. S. Negi**  
Assistant Professor &  
Chairman



**Department of Plant Pathology**  
Banda University of Agriculture  
& Technology- 210001  
**Dated:** 25.11.2020

## *Certificate-I*

This is to certify that the thesis entitled “**Studies on epidemiology and management of Alternaria blight of mustard**” submitted in partial fulfillment of the requirement for award of the degree of **Master of Science (Agriculture)** in **Plant Pathology**, College of Agriculture, Banda University of Agriculture and Technology, Banda is a genuine record of bonafide research work carried out by **Mr. Pradip Kumar, Id. No. 1021**, under my guidance and supervision. The results of the investigation in this thesis have not so far been submitted for any other degree or diploma.

It is further certified that the help or information received during the course of investigation and preparation of the thesis have been duly acknowledged.

**(H. S. Negi)**  
**Chairman, Advisory Committee**

**Endorsed:**

**Head of Department**

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We, undersigned members of the advisory committee of **Mr. Pradip Kumar, Id. No. 1021**, a candidate for the degree of **Master of Science (Agriculture)** in **Plant Pathology** have gone through the manuscript of the thesis and agreed that the thesis entitled “**Studies on epidemiology and management of Alternaria blight of mustard**” may be submitted in the partial fulfillment for award of the degree.

**Endorsed:**

**Dr. H. S. Negi**  
Assistant Professor  
Chairman, Advisory Committee

**Dr. Durga Prasad**  
Assistant Professor  
Co-Advisor

**Head of Department**

**Dr. Dinesh Sah**  
Associate Professor  
Co-Advisor

**Dr. Vishal Chugh**  
Assistant Professor  
Co-Advisor

**Dr. Mukul Kumar**  
Professor  
Registrar Nominee

### ***Certificate – III***

This is to certify that the thesis entitled “**Studies on epidemiology and management of Alternaria blight of mustard**” submitted by **Mr. Pradip Kumar, Id. No. 1021**, in partial fulfillment of the requirement for award of the degree of **Masters of Science (Agriculture)** in **Plant Pathology**, College of Agriculture, Banda University of Agriculture & Technology, Banda was examined and approved on \_\_\_\_\_

**(H. S. Negi)**  
**Chairman, Advisory Committee**

**Name & Signature**  
**External Examiner**

**Endorsed:**

**Advisory Committee**

**(Durga Prasad)**  
**Co-Advisor**

**Head of Department**

**(Dinesh Sah)**  
**Co-Advisor**

**Dean**  
**College of Agriculture**

**(Vishal Chugh)**  
**Co-Advisor**

**(Mukul Kumar)**  
**Registrar Nominee**

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---

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## ABBREVIATIONS

PDA	Potato Dextrose Agar
CMA	Corn Meal Agar
@	at the rate
%	Per cent
±	Plus minus
<i>et al.</i>	And other
°C	Degree Celsius
RH	Relative humidity
Cm	Centimetre
g	Gram
i.e.	that is
ml	milliliter
lt	Litre
Kg	Kilogram
BOD	Biological Oxygen demand
viz.	namely
DAS	Days after sowing
Fig.	Figure
ha	hectare
CD	Critical difference
SE <sub>(m)</sub>	Standard error of mean
q	quintal
mm	millimeter
RBD	Randomized Block Design
CRD	Completely Randomized design
etc.	Et cetra
mg	milligram
e.g.	exempli gratia (For Example)
pH	Potential of hydrogen
/	Per
conc.	concentration
ppm	Parts per million
Psi	Pound per square inch
PDI	Per cent disease index
r	Correlation coefficient
R <sup>2</sup>	Coefficient of determination
AUDPC	Area under disease progress curve
EC	Emulsifiable Concentrate
SC	Suspended Concentrate
WP	Wettable powder
hrs	Hours
>	More than
WAS	Weeks after sowing

## **Banda University of Agriculture and Technology, Banda**

**Name:** Pradip Kumar      **Id. No.:** 1021  
**Semester:** IV                      **Degree:** M. Sc. (Agriculture) Plant Pathology  
**Year of admission:** 2018                      **Department:** Plant Pathology  
**Major:** Plant Pathology      **Minor:** Entomology  
**Thesis Title:** Studies on epidemiology and management of *Alternaria* blight of mustard

### **ABSTRACT**

The present investigation entitled “Studies on epidemiology and management of *Alternaria* blight of mustard” was carried out in the laboratory and farm of the Department of Plant Pathology, College of Agriculture, Banda University of Agriculture and Technology, Banda, UP during 2018-2020. After isolation and purification, the pathogenicity test of the pathogen (*Alternaria brassicae*) was conducted in pots. In screening of 32 oilseed brassicas varieties/lines of SBG-18 series, no germplasm was found to be immune or highly resistant, one germplasm was found as resistant, 5 germplasm were moderate resistant, 1 germplasm was moderate susceptible, 17 germplasm were susceptible and 8 germplasm were highly susceptible. Out of the 60 germplasm of the UDN-18 series, none was found as immune or highly resistant, whereas, 2 germplasm were found as resistant, 2 germplasm were moderately resistant, 8 germplasm were moderately susceptible, 47 germplasm were susceptible and 1 germplasm was found as highly susceptible. In epidemiological studies the first symptom of the disease in Varuna and Ganga varieties of Indian mustard appeared on 49<sup>th</sup> meteorological week i.e. eight weeks after sowing during which the maximum average temperature recorded was 22.14°C, minimum average temperature was 10.29°C, average morning RH was 91.57%, average noon RH was 60.57%, average evening RH was 80.57% and total weekly rainfall of 19.2 mm was received. Per cent disease index of *Alternaria* blight of mustard was reported positively correlated with the average minimum temperature whereas, it was significantly negative correlated with all other parameters in both the varieties. Regression coefficient was significant at 5% level with Maximum Temp. and RH Noon whereas, it was significant with Minimum Temp. and RH Evening at 1% level for both Varuna and Ganga. Coefficient of determination ( $R^2$ ) of 0.812 and 0.818 was calculated in Varuna and Ganga, respectively. In Varuna and Ganga varieties of Indian mustard sown four times at seven days interval, lowest mean PDI of the disease (15.49 and 14.43%) was recorded from the 1<sup>st</sup> sown plots on 20<sup>th</sup> October, 2019 and the highest mean PDI of 28.57 and 26.71% was recorded from 4<sup>th</sup> sowing on 10<sup>th</sup> November, 2019 in variety Varuna and Ganga, respectively. Maximum mean yield of 19.18 q/ha was obtained from mustard crop sown on 1<sup>st</sup> date which significantly reduced with the delay in sowing and was minimum in 4<sup>th</sup> sowing (13.39 q/ha). Ganga variety resulted in more average yield (17.10 q/ha) as compared to Varuna (15.41 q/ha) which also differed significantly from each other. Minimum AUDPC of 1236.11 and 1146.28 was resulted in 1<sup>st</sup> sowing whereas, maximum AUDPC of 2007.72 and 1862.14 was resulted in 4<sup>th</sup> sowing of Varuna and Ganga, respectively. Among six different systemic and combination fungicides evaluated *in vitro* against *Alternaria brassicae*, propiconazole, hexaconazole and captan + hexaconazole were the most effective with 100 per cent mycelial growth inhibition in all the tested concentrations. Whereas, among three non-systemic fungicides, mancozeb was the most effective with 94.09 per cent average mycelial growth inhibition. During *in vivo* evaluation of nine fungicides, propiconazole resulted as most effective to reduce the disease severity of *Alternaria* blight to 17.84% followed by captan + hexaconazole (19.87%) and hexaconazole (20.20%) and these fungicides did not differ significantly with each other. Maximum yield was also obtained with propiconazole (21.56 q/ha) followed by captan + hexaconazole (20.26 q/ha) and hexaconazole (19.82 q/ha).

**(H. S. Negi)**  
**Advisor**

**(Pradip Kumar)**  
**Student**

## बाँदा कृषि एवं प्रौद्योगिक विश्वविद्यालय, बाँदा

नाम— प्रदीप कुमार

आई. नं.— 1021

समेस्टर— IV

डिग्री— एम.एस.सी (कृषि) पादप रोग विज्ञान

प्रवेश वर्ष— 2018

विभाग— पादप रोग विज्ञान

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लघु विषय— कीट विज्ञान

शीर्षक— सरसों के अल्टरनेरिया झुलसा रोग में महामारी विज्ञान एवं प्रबंधन पर अध्ययन

### सारांश

“सरसों के अल्टरनेरिया झुलसा रोग में महामारी विज्ञान एवं प्रबंधन पर अध्ययन” विषयक मौजूदा शोध को कृषि महाविद्यालय, बाँदा कृषि एवं प्रौद्योगिकी विश्वविद्यालय, बाँदा के पादप रोग विज्ञान विभाग की प्रयोगशाला और शोध प्रक्षेत्र में 2018-2020 के दौरान किया गया। झुलसा रोग के रोगकारक को पृथक कर कृत्रिम माध्यम पर संवर्धित करने के उपरान्त *अल्टरनेरिया ब्रासिकी* की रोग उत्पन्न करने की क्षमता का परीक्षण किया गया। एसबीजी -18 श्रृंखला की 32 ब्रेसिका— तिलहन जनन द्रव्यों के मूल्यांकन में कोई जनन द्रव्य प्रतिरक्षा या अत्यधिक रोगरोधी नहीं पाया गया जबकि एक जनन द्रव्य रोगरोधी, 5 जनन द्रव्य मध्यम रोगरोधी, 1 जनन द्रव्य मध्यम रोगग्राही, 17 जनन द्रव्य रोगग्राही और 8 जनन द्रव्य अति रोगग्राही थे। यूडीएन-18 श्रृंखला के 60 जनन द्रव्यों में कोई भी प्रतिरक्षा या अत्यधिक रोगरोधी नहीं पाया गया, जबकि 2 जनन द्रव्य रोगरोधी, 2 जनन द्रव्य मध्यम रोगरोधी, 8 जनन द्रव्य मध्यम रोगग्राही, 47 जनन द्रव्य रोगग्राही और 1 जनन द्रव्य अति रोगग्राही पाये गये। भारतीय सरसों की वरुणा और गंगा किस्मों में रोग के फैलाव के अध्ययन में रोग का प्रथम लक्षण 49 वें मौसमी सप्ताह अर्थात् बुवाई के आठ सप्ताह के बाद दिखाई दिया, जिसमें अधिकतम औसत तापमान 22.14° से0, न्यूनतम औसत तापमान 10.29° से0, औसत सुबह सापेक्षिक आर्द्रता 91.57%, औसत दोपहर सापेक्षिक आर्द्रता 60.57%, औसत संध्या सापेक्षिक आर्द्रता 80.57% और कुल साप्ताहिक वर्षा 19.2 मिमी प्राप्त हुई थी। सरसों के अल्टरनेरिया ब्लाइट के प्रतिशत रोग तीव्रता सूचकांक (PDI) को दोनों किस्मों में औसत न्यूनतम तापमान के साथ सकारात्मक रूप से जबकि अन्य सभी मापदंडों के साथ नकारात्मक सहसंबंधित पाया गया। प्रतिगमन गुणांक 5% के स्तर पर अधिकतम तापमान एवं दोपहर सापेक्ष आर्द्रता के साथ सार्थक तथा न्यूनतम तापमान एवं संध्या सापेक्ष आर्द्रता के साथ 1% के स्तर पर सार्थक पाया गया। निर्धारण के गुणांक (R<sup>2</sup>) की वरुणा और गंगा में गणना क्रमशः 0.812 और 0.818 पायी गई। भारतीय सरसों की वरुणा और गंगा किस्मों में सात दिनों के अंतराल पर की गई चार बार बुवाई में सबसे कम प्रतिशत रोग तीव्रता सूचकांक (PDI) (15.49 और 14.43%) 20 अक्टूबर, 2019 की प्रथम बुवाई तथा उच्चतम पीडीआई (28.57 और 26.71%) 10 नवंबर, 2019 की अंतिम बुवाई में पाया गया। 19.18 कुंतल प्रति हेक्टेयर की अधिकतम उपज प्रथम बुवाई में बोई गई सरसों की फसल से प्राप्त हुई, जो बुवाई में देरी के साथ काफी कम होते हुए और अंतिम बुवाई में न्यूनतम (13.39 कुंतल प्रति हेक्टेयर) थी। गंगा किस्म की औसत उपज (17.10 कुंतल प्रति हेक्टेयर) वरुणा किस्म (15.41 कुंतल प्रति हेक्टेयर) की तुलना में अधिक पायी गयी। 1236.11 और 1146.28 की न्यूनतम AUDPC पहली बुवाई में तथा 2007.72 और 1862.14 की अधिकतम AUDPC अंतिम बुवाई में पायी गयी। *अल्टरनेरिया ब्रासिकी* का प्रयोगशाला में छह अलग-अलग अन्तःप्रवाही और संयोजन कवकनाशकों से मूल्यांकन में प्रोपिकोनाजोल, हेक्साकोनाजोल और कैप्टान+हेक्साकोनाजोल सबसे प्रभावी थे और सभी 100 प्रतिशत कवकजाल विकास अवरोध रहे। जबकि, तीन सतहस्पर्शी कवकनाशियों में, मैन्कोजेब (94.09) प्रतिशत औसत कवकजाल विकास अवरोध के साथ सबसे प्रभावी था। नौ कवकनाशकों के प्रक्षेत्र मूल्यांकन में, प्रोपिकोनाजोल सबसे प्रभावी कवकनाशक पाया गया जिसमें न्यूनतम अल्टरनेरिया झुलसा रोग प्रतिशत रोग तीव्रता सूचकांक (17.84%) पाया गया, इसके बाद कैप्टान + हेक्साकोनाजोल (19.87%) और हेक्साकोनाजोल (20.20%) सबसे प्रभावी कवकनाशी रहे। अधिकतम उपज भी प्रोपिकोनाजोल (21.56 कुंतल प्रति हेक्टेयर) से प्राप्त की गई, इसके बाद कैप्टान + हेक्साकोनाजोल (20.26 कुंतल प्रति हेक्टेयर) और हेक्साकोनाजोल (19.82 कुंतल प्रति हेक्टेयर) सबसे प्रभावी पाये गये।

(एच. एस. नेगी)  
सलाहकार

(प्रदीप कुमार)  
छात्र

# INTRODUCTION

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Rapeseed-mustard is one of the most important oilseed crops belonging to *Brassica* spp. and plays an important role in the agricultural economy of India. It is being grown predominantly on varied soils of diverse agro-climatic regions in the country. Rapeseed-mustard is an important source of edible oil with lowest amount of saturated fats and their leafy vegetable is also rich in minerals, vitamins, fiber and antioxidants. The crop is also utilized for industrial use such as manufacturing soaps, paints, hairs oils, varnishes, lubricants, textiles, auxiliaries and various other products. Oilseed brassicas have been reported to contain 38-57% eruric acid, 4.7-13% linolenic acid, 27% oleic acid and 10-12% of linoleic acid (Kumar *et al.*, 2014).

Mustard is grown in sub-tropical and tropical countries in the world comprising eight cultivated crops in family Cruciferae (Brassicaceae). India is third largest oil economy in the world after USA and China. The current production of all oilseeds in the country meet only 50% of domestic need of edible oil and the deficit is being covered with import of palm oil of more than Rs. 50,000 crores per annum. Mustard (*Brassica juncea* (L.) Czerm. & Coss.) is regarded as the third most important oilseed crop in the world after soybean and palm oil.

Yield of most of the oilseed crops in India is less than the world and with present level of production and productivity, increase in population and better living standards the demand of edible oil is anticipated to increase further in future. The demand of edible oil has been estimated to increase upto 11.12 million tonnes by 2030 (Paroda and Kumar, 2000) which equals to the production of 32.35 million tonnes of oilseeds in the year 2030.

India is one of the leading countries with respect to production, consumption and import of the vegetable oils (Singh *et al.*, 2009). In world, 63.09 million tonnes of rapeseed-mustard is produced over 37.0 million ha acreage with the productivity of 18.50 q/ha. India is the third largest rapeseed-mustard growing country producing 9.34 million tonnes oilseeds and 2.9 million tonnes of oil from an area of 6.23 million ha with productivity of 14.99 q/ha. Uttar

Pradesh produces 1.12 million tonnes of rapeseed-mustard from 0.753 million ha land with productivity of 14.83 q/ha and sharing 11.96% of the total countries rapeseed-mustard oilseed production (Anonymous, 2019). In Bundelkhand region of Uttar Pradesh, rapeseed-mustard crop is being cultivated in an area of about 70875 ha with production of 71267 tonnes and productivity of 10.06 q/ha only (Anonymous, 2018).

One of the reasons behind low productivity of the rapeseed-mustard in the country and especially in the Bundelkhand region of Uttar Pradesh is various biotic stresses mainly the fungal diseases. The crop is affected by many fungal diseases among which *Alternaria* blight caused by *Alternaria brassicae* (Berk.) Sacc. and *Alternaria brassicola* (Schw.) Wiltshire is one of the most serious ones. The pathogen of *Alternaria* blight can be isolated from affected plant parts like leaves, silique and stems. Infection of pathogen at seedling stage may also leads to the death of young plants. The disease has been reported widespread and destructive throughout the world generally resulting in heavy losses in seed yield and quality (Kotle, 1985) causing a yield loss of 10-71% in India (Chattopadhyay, 2008) and upto 30% in Canada (Conn *et al.*, 1990). Reduction in grain weight of 24% in mustard and 23% in yellow sarsoan has also been reported from India (Kolte *et al.*, 1987). Chahal (1982) has reported 12.9-47% yield loss of mustard due to *Alternaria brassicae* infection. Shrestha *et al.* (2005) have also reported 32.57% yield loss of mustard due to *Alternaria* blight.

Epidemiological factors like temperature, relative humidity or duration of leaf wetness, rainfall etc. plays an important role in the primary and secondary infection of any disease. A particular maximum and minimum temperature and per cent relative humidity during different periods of the day are also responsible in determining the infection and development of *Alternaria* blight disease (Mehta, 2019). Similarly date of sowing also determines the extent of severity of *Alternaria* blight of mustard (Alam *et al.*, 2014). Therefore, role of different weather parameters in the initiation, development and spread of the disease can be explored in the Bundelkhand region of the Uttar Pradesh.

Various methods have been evaluated for the management of *Alternaria* blight of rapeseed-mustard throughout the world and among them, judicious use of fungicides still is one of the most effective management measures. Various fungicides have been evaluated in

different parts of the world under *in vitro* as well as *in vivo* conditions as seed treatment and foliar sprays. Some of the prominent fungicides evaluated best against the disease are carbendazim, metalaxyl, iprodione and EBI fungicides (Chattopadhyay and Bhunia, 2003; Rai *et al.*, 2014; Bisht and Tewari, 2016). Different novel fungicides thus can be evaluated for their judicious use and recommendation for management of *Alternaria* blight disease.

Therefore, keeping in view the importance of *Alternaria* blight of mustard and the losses caused by it, the present investigation was proposed with the following objectives:

1. Screening of rapeseed-mustard germplasm for *Alternaria* blight.
2. To study the epidemiological parameters on development and spread of the disease.
3. *In vitro* and *in vivo* evaluation of fungicides against *Alternaria brassicae*.

## **REVIEW OF LITERATURE**

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Rapeseed-mustard is one of the most important oilseed crops being grown in India primarily for edible oil. The crop also plays an important role in the agricultural economy of the country. Alternaria blight of rapeseed-mustard is caused by *Alternaria brassicae* (Berk.) Sacc. and *Alternaria brassicola* (Schw.) Wiltshire of which former is the most serious ones responsible for reduced quality and quantity of the oilseeds. The disease is greatly influenced by weather parameters and mostly higher disease incidence occurs in regions experiencing wet growing season with high relative humidity. Management of the disease through judicious use of novel fungicides still is most effective measures due to absence of resistant varieties against the disease.

### **2.1 Historical Background of the Pathogen**

*Alternaria* genus was first described by Nees (1817) with the type species *A. tenuis* which was later renamed as *Alternaria alternata*. Berkeley (1836) was first to notice the fungal infection on plants belonging to the family Brassicaceae and identified the fungus as *Microsporium brassicae* (Berk.) which was later renamed as *Alternaria brassicae* (Berk.) Sacc. by Saccardo (1886). In India, Alternaria blight was first reported on sarsoan from Tirhoot in 1901 (Butler, 1918) but the fungus was thought to be new and described as *Sporodochium brassicae*. Later, Mason (1928) first observed the *Alternaria* sp. from a herbarium material of mustard from Pusa (Bihar).

### **2.2 Symptomatology:**

Symptoms of Alternaria blight in rapeseed-mustard are characterized by formation of spots on leaves, siliquae and stem. *A. brassicae* and *A. brassicola* can affect host species at all stages of growth, including seed. On seedling, symptoms include dark stem lesions immediately after germination that can result in damping-off, or stunted seedling. *A. raphani* produce black stripe or dark brown, sharp-edged lesion on hypocotyls of the seedling. It grows

in vascular system and rapidly infects the entire seedling (Valconen and Koponen, 1990). Chupp and Sherf (1960) reported that the spots produced by *A. brassicae* appear to be usually grey in colour compared to black sooty velvety spots produced by *A. brassicola*. Spots produced by *A. raphani* shows distinct yellow halos around them. However, the symptoms may vary with the host and environment. Symptoms are first visible on lower leaves with the appearance of black points, which later develop into prominent, round, concentric spots of various sizes (Kumar *et al.*, 2104b). With progress of the disease, symptom appears on middle and upper leaves with smaller sized spots followed by defoliation of lower leaves (Singh, 1998).

### **2.3 Isolation and Identification**

Maximum mycelial growth of *A. brassicae* seven days after inoculation in potato dextrose agar medium (90.00 mm) followed by mustard leaf dextrose agar medium (70.00 mm) has been recorded by Singh *et al.* (2017) while, minimum growth of 20.36 mm was recorded in pea husk dextrose agar medium. Potato dextrose agar and mustard leaf extract media have been reported best by Kumar and Singh (2018) among the eight tested media for growth of 20 isolates of *A. brassicae* while carrot agar was reported least supportive medium. Potato dextrose agar medium was also reported best for the growth of *A. brassicae* by Sharma *et al.* (2013) and Pramila *et al.* (2014).

Taxonomy, parasitism and economic significance of *Alternaria* genus was studied in detail by Elliot (1917). Jolly (1964) described the morphological variability in *Alternaria* spp. and later he divided the species into three sections and gave a key for identification of the most common species of *Alternaria* genus. Subramanian (1971) described the Indian species of *Alternaria* in detail. The morphological characteristics of various *Alternaria* spp. are described in Dematiaceae family. Simmons (2007) compiled his work on the fungus in his book “*Alternaria and Identification Manual*” in which he described the taxonomy, nomenclature and classification for accurate identification of different species of *Alternaria*.

Hyphae of *A. brassicae* has been reported as branched, septate, hyaline, smooth with 4 to 8  $\mu\text{m}$  thickness. Conidiophores appeared from the hyphae in groups of 2 to 10 or more. Conidia were solitary or occasionally in chains of up to four, with 16 to 19 (usually 11 to 15) transverse septa and 0 to 8 (usually 0 to 3) longitudinal or oblique septa, pale or very pale olive or grayish olive in colour, 75 to 350  $\mu\text{m}$  long and usually 20 to 30  $\mu\text{m}$  (sometimes 40  $\mu\text{m}$ ) thick in the broadest part. The beak was 1/3 to 1/2 the length of conidium (Anonymous, 1968).

Kolte (1985) observed mycelium of *A. brassicae* as septate and brown to brownish grey coloured. Conidiophores as dark, septate measuring 14-74  $\times$  4-8  $\mu\text{m}$ . Each of the conidia had 10 to 11 transverse septation and 0 to 6 longitudinal septation, often obclavate, muriform with prominent long beak of 148-184  $\mu\text{m}$  long and 17 to 24  $\mu\text{m}$  thickness. Singh (1998) illustrated conidia of *A. brassicae* as dark, obclavate, muriform, borne singly or in short chains measuring 125 to 225  $\times$  16 to 28  $\mu\text{m}$  in dimensions.

Singh *et al.* (2015) observed that length and width of conidiophores ranged from 36.82 to 63.45  $\mu\text{m}$  and 4.73 to 6.58  $\mu\text{m}$ , respectively. The average conidiophore septations ranged from 4.53 to 6.25 in different isolates of *A. brassicae*. The conidial length ranged from 104.0 to 142.47  $\mu\text{m}$ , conidial width 11.62 to 16.95  $\mu\text{m}$  and conidial beak length ranged from 43.35 to 70.57  $\mu\text{m}$  in different isolates of *A. brassicae*. Number of transverse and longitudinal septa ranged from 6.0 to 8.3 and 0.25 to 2.75, respectively. Maximum growth among ten isolates of *A. brassicae* was noted at 25<sup>0</sup>C followed by 30<sup>0</sup>C and 20<sup>0</sup>C.

## **2.4 Pathogenicity**

Pathogenicity of four different isolates viz. DEL, PNT, MRT and ND of *A. brassicae* on *Brassica juncea*, *Sinapis alba* and *Camelina sativa*, having different degree of resistance against the pathogen was tested by Yadav *et al.*, (2019) and observed highest pathogenicity in PNT isolate which produced largest sized lesions of 1.23  $\pm$  0.24 cm in *B. juncea* whereas, DEL isolate produced smaller sized lesions [0.96 cm ( $\pm$  0.21)] at 12 days' post inoculation. They concluded PNT isolate as highly pathogenic followed by ND and MRT isolates.

## 2.5 Evaluation of Germplasm of Rapeseed-mustard

In a screening test, three genotypes viz. PR8988, PR9024 and Kranti exhibited partial resistance with lowest severity of Alternaria blight and yield potential of the genotypes was negatively correlated with the disease severity (Kumar, 2008).

In screening of eighty one genotypes of Indian mustard against Alternaria blight under natural epiphytic condition it was reported that none of the genotype was completely free from disease. Only one genotype- YET 25 was found resistant against the disease however, line 10 and 61 were reported moderately resistant and moderately susceptible, respectively (Singh *et al.*, 2009).

Rahman *et al.* (2010) recorded disease severity index of 26 varieties/lines of rapeseed-mustard against Alternaria blight and found none of the lines as highly resistant or resistant, while six among them reported to be moderately resistant.

Yadav *et al.* (2014) in an assessment trial on resistant source against Alternaria blight in rapeseed-mustard reported none of the 31 varieties/line screened as completely disease free while, variety NPN-1 was found to be resistant with 9.2% incidence of disease only. Five genotypes viz. NPC-15, PBC-2004-1, PRQ-2004-1, NPR-3-06 and PR 2003-30 were found to be moderately resistant and 10 lines were reported as moderately susceptible exhibiting 26-50% disease incidence. They also categorized nine lines as susceptible (51-75% disease incidence) and highly susceptible group comprised of 6 lines.

Among the different genotypes evaluated for their reaction against Alternaria blight of mustard, four genotypes were rated as moderately resistant while sixteen genotypes were marked as moderately susceptible and nine genotypes were rated under susceptible group (Talukdar and Das, 2015).

Singh *et al.* (2018a) evaluated 200 genotypes for their resistance to Alternaria blight and none of the genotypes were found disease free or highly resistant, only 7 genotypes (DLSC-1, DRMR-261, DRMR-270, GSC-101, GSL-1, NPC-20 and PHR-2) were found resistant while 15 genotypes were rated as moderately resistant. Rest of the genotypes either

recorded susceptible or highly susceptible. Out of 200 promising genotypes evaluated for resistance, Singh *et al.* (2018b) found none of the entry as resistant whereas, twenty-two genotypes were reported moderately resistant and 63 genotypes were moderately susceptible.

Summuna *et al.* (2018) among twenty seven genotypes screened for their reaction against *Alternaria* blight rated two genotypes viz. RH-8113 and PC-5 as moderate resistant, four genotypes viz. GM-3, RH-1359, RH-819 and JM-1 as moderately susceptible, eighteen genotypes viz. Geeta, Pusa Bahar, Rohini, RH-30, Shivani, RH-781, RGN-13, GM-2, RRN-505, Krishna, GM-1, Pusa Jaganath, Vaibhav, RSPN-602, DGS-1, RSPN-25, RSPN-2 and RSPR-69 as susceptible. They also reported three genotypes viz. Kranti, Varuna and CS-54 as highly susceptible.

Kumar *et al.* (2019) in an experiment reported 4 genotypes namely IC-399840, IC-312496, IC-342778 and IC-399802 with lowest AUDPC values exhibiting tolerance and 4 genotypes namely IC-426392, Varuna, IC-264131 and IC-491566 as highly susceptible to *Alternaria* blight.

## **2.6 Epidemiological Studies**

Epidemiological studies are necessary to find out critical environmental parameters favoring infection and development of disease. Many workers have find out the effect of temperature, relative humidity (RH), rainfall and sunshine hours on occurrence of blight on the oilseed-brassicac (Dang *et al.*, 1995).

### **2.6.1 Effect of weather parameters**

Kundu and Patra (1991) reported that the spore germination of *A. brassicola* was high over a temperature range of 25-35°C.

Gupta *et al.* (2003) in an experiment reported that eighty five days old mustard plants showed highest disease severity because maximum temperature (20.4-31.6°C) and minimum temperature (4.9-14.4°C) were significantly negatively correlated, while maximum relative humidity (80-94%) and minimum relative humidity (33-56%) had a significant positive

correlation with disease severity. They also fitted the prediction equations for forecasting of the disease at different growth stages of the crop.

Shrestha *et al.* (2005) observe increase in number of spots in February from only few spots in lower leaves during third week of January when maximum temperature ranged 15-20°C, minimum temperature ranged 1-5°C and relative humidity was more than 80%.

Maximum temperature ranging 26-29°C, minimum temperature of 14-15°C and average relatively humidity of more than 65% also favoured the development of Alternaria blight in mustard (Sangeetha and Siddaramaiah, 2007).

Maximum disease intensity of 53.3% and 25.7% on leaves and siliquae, respectively was observed during January-February and maximum temperature positively correlated with disease index (Jha *et al.*, 2013). It was also observed that maximum temperature of 23.2°C and maximum and minimum relative humidity (RH) of >80% and 66%, respectively, with correlation coefficient (r) =0.735 for minimum temperature and r=0.515 of minimum RH favoured the development of the disease.

Mahapatra and Das (2014) reported that in early sown mustard crop on 20th October sowing, T<sub>min</sub>, RH<sub>min</sub> and WV<sub>morning</sub> influenced the disease progression with linear prediction equations as  $Y = 3.203 - 0.356 (T_{min}) + 0.015 (RH_{min})$ .

In sowing of mustard from 20<sup>th</sup> October to 5<sup>th</sup> November, only minimum temperature ranging 9.69 to 12.04°C had significant negative correlation, while minimum RH (44.9 to 60.2%), wind velocity during morning (0.55 to 1.04 Km/h) and total rainfall (5.74 mm) had positive significant correlation with disease progression upto 59% (Mahapatra and Das, 2015). Whereas, in crop sown on 20<sup>th</sup> November, minimum temperature (9.69 to 15.74°C), minimum (39 to 88%) and maximum (96 to 99%) relative humidity, wind velocity during morning (0.4 to 1.29 Km/h), bright sunshine hours (3.8 to 9.0 h) and total rainfall (69.6 mm) had positive significant correlation with disease progression upto 62%.

It was observed that the maximum temperature, minimum temperature and sunshine hours showed a significant positive correlation with disease severity while morning relative humidity had a significant negative correlation with disease severity (Jain and Sandhu, 2019).

Mehta (2019) observed the development of *Alternaria* blight to favour by the maximum temperature of 20–25°C, minimum temperature of 15°C, relative humidity in morning > 90% and relative humidity in evening > 50%.

Dhaliwal and Singh (2020) reported that the maximum temperature ranged 15.7–30.3 °C and minimum temperature ranging 3.3–12.6°C had positive correlation with disease severity.

### **2.6.2 Effect of date of sowing**

Bali *et al.* (1992) observed a higher yield (14.4 q/ha) when *Brassica juncea* crop was sown on 25<sup>th</sup> September as compared to the crop sown on 15<sup>th</sup> October and 4<sup>th</sup> November which produced yield of 12.7 and 5.1 q/ha, respectively and was 13.4 and 18.4 percent higher than 15<sup>th</sup> October and 4<sup>th</sup> November sowing, respectively.

Patel *et al.* (1994) experimented on mustard under three dates of sowing viz. 15<sup>th</sup> October, 25<sup>th</sup> October and 4<sup>th</sup> November and recorded highest yield of 1342 Kg/ha in crop sown on first date (15<sup>th</sup> October) followed by third date of sowing (1154 Kg/ha). Rashid *et al.* (1995) reported that the mustard sown in month of October or before 2<sup>nd</sup> November had lower infection of *Alternaria* and the infection increased with delay in sowing.

Gupta *et al.* (2003) in a field experiment on epidemiology of *Alternaria* blight evaluated that the rapeseed-mustard crop sown on 21<sup>st</sup> October had significantly less disease severity which enhanced with subsequent sowing dates. Authors also reported that the rapeseed cultivar PT-303 showed significantly more PDI followed by Divya and Kranti on all the sowing dates.

Khatun *et al.* (2011) carried out a trial on the effect of four different dates of sowing and varieties on the severity of *Alternaria* blight of mustard and concluded that the disease

severity differs significantly among the varieties of *Brassica* spp. with *B. campestris* having higher disease severity compared to *B. napus* and *B. juncea*.

Alam *et al.* (2014) reported from their studies that first sowing date (25 October) produced a good yield than the later dates of sowing. Similar results were also reported by Rahman and Shahjahan, 1986; Howlader *et al.*, 1989.

Gawariya *et al.* (2015) also observed that crop sown on 1<sup>st</sup> October gave significantly higher yield attributing characters viz. number and weight of silique/plant, dry matter accumulation and seed yield (2013 Kg/ha) as compared to the crop sown on 31<sup>st</sup> October and 15<sup>th</sup> November.

Jain and Sandhu (2019) in an experiment on two mustard cultivars (RLC-3 and PBR-357) to evaluate the effect of different dates of sowing viz. 10<sup>th</sup> October, 5<sup>th</sup> November and 1<sup>st</sup> December on disease severity resulted that late sown crop showed higher disease severity of 44.2 & 51.5% followed by the normal (39.7 & 45.5%) and early sown crop (31.5 & 40.0%), respectively for RLC-3 and PBR-357. Area under disease progress curve (AUDPC) was also highest in late sowing (162) followed by normal (148) and early (126) sowing.

Dhaliwal and Singh (2020) also reported a significant difference among the sowing dates and varieties of mustard. RLC-3 showed maximum PDI (52.19%) whereas, minimum PDI (0.98%) was reported in PC-6. Maximum seed yield (20.37 q/ha) was recorded in 1<sup>st</sup> sowing followed by 2<sup>nd</sup> sowing (12.59 q/ha). They also recorded highest area under disease progress curve (AUDPC) in RLC-3 variety (3885.91) of mustard with 3<sup>rd</sup> sowing and the lowest AUDPC was recorded in PC-6 (54.77) with 1<sup>st</sup>sowing.

## **2.7 Management Studies**

Various methods have been evaluated for the management of *Alternaria* blight of mustard throughout the world and among them; judicious use of fungicides still is one of the most effective management measure. Various fungicides have been evaluated in different

parts of the world under *in vitro* as well as *in vivo* conditions as seed treatment and as well as foliar sprays.

### 2.7.1 Evaluation of fungicides

Among mancozeb, Ridomil MZ (mancozeb + metalaxyl), captan, Rovral (iprodione), Baylton (tridimenfon) and copper oxychloride evaluated under *in vitro* and *in vivo* conditions against *Alternaria* blight (*Alternaria brassicae*) and white rust (*Albugo candida*) of Indian mustard, all the fungicides significantly inhibited the pathogen growth *in vitro*. In field evaluations, Rovral was most effective in controlling of *Alternaria* blight with mean disease intensity of 8.75 and 5.6 per cent on leaves and pods, respectively. Highest yield was resulted with Rovral (2.1 tonnes/ha) followed by mancozeb and Ridomil MZ, each recording a yield of 1.9 tonnes/ha (Godika *et al.*, 2001).

Yadav *et al.* (2002) reported that PBR 91 Cv. of mustard sown in mid October after seed treatment with metalaxyl @ 6 g/Kg seed followed by first spray of metalaxyl + mancozeb @ 0.25% at disease appearance followed by two subsequent sprays of mancozeb @ 0.2% at 20 days' interval reduced the white rust and *Alternaria* blight on leaf and inflorescence and also improved seed yield.

Spray of Iprodione (500g a.i. per h) during the early pod stage was found most effective in controlling *Alternaria* blight with increased seed yield of mustard by 24-59 per cent (Mukherjee *et al.*, 2003). Chattopadhyay and Bhunia (2003) evaluated different fungicides viz., mancozeb 0.2%, captan 0.2%, metalaxyl MZ 0.25%, iprodione 0.2%, triadimefon 0.05%, copper oxychloride 0.3% and propineb 0.2% against *Alternaria* leaf blight of rapeseed-mustard (*Alternaria brassicae*) among which best control was observed with iprodione followed by mancozeb.

Singh and Singh (2005) reported that three foliar sprays of mancozeb 75% WP (0.2%) at 15 days' interval beginning from 45 days after sowing, resulted in lowest *Alternaria* blight incidence, highest seed yield and highly cost benefit ratio of 1:5.2. Mondal *et al.* (2007) tested six fungicides viz. azoxystrobin (Amistar), trifloxystrobin + tebuconazole (Nativo), mancozeb

(Dithane M-45), difenconazole (Score) and azadirachtin (Neemarin) against *Alternaria* blight of rapeseed-mustard under *in vitro* as well as field conditions and found that all fungicides were significantly effective in reducing disease severity over control and increased the seed yield. However, two sprays of Nativo @ 1g/lit H<sub>2</sub>O resulted in lowest disease severity, highest seed yield and significant increase in test weight.

Among twelve different chemicals, extracts and bio-control agents, mancozeb resulted in the lowest mean severity of *Alternaria* blight of Indian mustard i.e. 33.1% on leaves and 26.3% on pods (Meena *et al.*, 2011). Chemicals also proved effective in reducing *Alternaria* blight severity on leaves and pods of Indian mustard (leaves = 36.3-37.9%; pods = 27.5-30.1%). Mancozeb also enabled increase in the dry seed yield of crop (2052 Kg ha<sup>-1</sup>) when compared to garlic (2006 Kg ha<sup>-1</sup>) and control (1561 Kg ha<sup>-1</sup>).

Singh *et al.* (2013) evaluated different fungicides and reported propiconazole 25EC @ 0.1% in maximum test weight and yield (6.057g and 1366.66 Kg/ha) of mustard.

Bal *et al.* (2014) reported Ridomil Gold MZ @ 0.25% as most effective fungicide against white rust while, Score 25EC @ 0.1% was most effective against *Alternaria* blight among the seven fungicides tested. Ridomil Gold MZ @ 0.25% also resulted in maximum increase in grain yield of 31.6 per cent.

Bio-efficacy of ten fungicides were evaluated *in vitro* against *Alternaria brassicae* in which Iprodione was found most effective and resulted significantly highest mean mycelial growth inhibition (100.00%). Mancozeb and carbendazim were the next best fungicides which recorded mean growth inhibition of 90.29 and 88.58 per cent, respectively (Harde and Atar, 2014).

Among the eight treatments, seed treatment with metalaxyl + carbendazim combination was most effective in reducing disease severity and also increasing yield (35.0 and 24.0 %) followed by carbendazim (31.5 and 23.3%) and metalaxyl (29.3 and 20.3%), respectively (Rai *et al.*, 2014).

Bisht and Tewari (2016) among the six fungicides tested against *Alternaria* blight of mustard observed iprodione and mancozeb @ 0.2% as most effective fungicides against the disease with 13.33 and 18.0% disease severity at pod stage, respectively.

Mahapatra and Das (2016) evaluated three fungicides (iprodione, propiconazole, mancozeb) at different doses (0.15, 0.20, 0.25, and 0.30%) on *Alternaria* blight of mustard. All three fungicides reduced the effect of *Alternaria* blight in comparison to control after 40 days showing minimum infection of *Alternaria* blight in leaf (13%) and silique (9.9%) when sprayed with iprodione @ 0.25% which also resulted in maximum yield (1682.6 Kg $ha^{-1}$ ) followed by propiconazole @ 0.30% (1539.3 Kg $ha^{-1}$ ) with cost benefit ratio of 1: 5.5 and 1: 3.5, respectively.

Singh *et al.* (2018a) evaluated six fungicides in thirteen treatment combinations against *Alternaria* blight of Indian mustard in which propiconazole 25 EC @ 0.1% resulted as most effective treatment with minimum PDI (18.97% and 20.70%) followed by propiconazole 25 EC @ 0.05% (22.0% and 24.73%) and hexaconazole 5 SC @ 0.1% with 23.30% and 25.27% in year 2013-14 and 2014-15, respectively. Propiconazole 25 EC @ 0.1% also resulted in avoiding highest test weight loss (34.92%) and highest yield loss (48.67%) followed by same fungicide @ 0.05%.

Singh *et al.* (2018b) through an experiment reported that seed treatment with metalaxyl @ 6g/Kg seed and spray of all fungicides, bio-agents and botanical extract, significantly reduced the *Alternaria* blight of mustard severity in comparison to the untreated control. Tebuconazole + trifloxystrobin @ 0.05% was found most effective fungicide followed by difenconazole @ 0.05%, iprodione @ 0.2%, tebuconazole @ 0.2%, captafol @ 0.2%, mancozeb @ 0.2% and antracol @ 0.25%, which showed 8.70%, 14.62%, 16.27%, 16.41%, 18.54%, 20.51%, 21.42% disease severity, respectively after third spray. Maximum seed yield (Kg/ha) and per cent increase in yield (1740.22, 37.90) was recorded with the treatment tebuconazole + trifloxystrobin @ 0.05% followed by difenconazole @ 0.05% (1629.61, 29.16), iprodione @ 0.2% (1617.11, 28.17) and tebuconazole @ 0.2% (1587.50, 25.85), respectively.

Manjhi *et al.* (2019) recorded minimum per cent disease intensity (14.58%) of *Alternaria* blight of mustard with spray of mancozeb followed by neem seed kernel extract (19.86%). The highest seed yield was also recorded for mancozeb (1225.27 Kgha<sup>-1</sup>), which was significantly superior over all other treatments and recorded 85.74 per cent increase in seed yield over control. The highest incremental economic benefit (Rs. 17105.7 ha<sup>-1</sup>) was also achieved with spraying of mancozeb followed by neem seed kernel extract (Rs. 16756 ha<sup>-1</sup>). Mancozeb spray at 40 and 60 days after sowing reduced the disease upto 31% over control under field conditions (Jha *et al.*, 2013).

## **MATERIALS AND METHODS**

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The present investigation was carried out in Banda, Uttar Pradesh. District Banda is located in geographical extends between 24° 53' to 25° 55' North latitudes and 80° 07' to 81° 34' East longitudes. The detail of materials and methods applied in the present investigation are as follows:

### **3.1 Materials**

#### **3.1.1 Glasswares**

The entire glasswares (Petri plates, conical flasks, measuring cylinders, beakers, funnels, pipettes, stirrer rod, spreader etc.) used during the course of study were of the Borosilcate quality obtained from Borosil India. All glasswares were kept in the cleaning solution containing 60g potassium dichromate ( $K_2Cr_2O_7$ ) and 60ml of concentrated sulphuric acid ( $H_2SO_4$ ) in 1lt water for 24 hours. Thereafter, the glasswares were cleaned thoroughly with liquid detergent solution and washed in running tap water.

#### **3.1.2 Equipments**

Equipments used during the study included compound microscope, BOD incubator, laminar air flow cabinet, water bath, hot air oven, microwave oven, refrigerator, distillation unit etc. Some other small materials including glass slides, cover slips, inoculating needle, cork borer, haemocytometer, ocular and stage micrometer etc. were also used.

#### **3.1.3 Sterilization**

Cleaned glasswares were sterilized in hot air oven at 160°C for 2 hours for further use. The culture medium was sterilized in an autoclave at 15 psi (1.05 Kg/cm<sup>2</sup>) pressure for 20 minutes. Metallic equipments like forceps, needle and cork borer were sterilized by dipping in alcohol and heating over red-hot flame of a spirit lamp. Surface sterilization of plant parts and

diseased materials were done by dipping them in 1 % sodium hypochlorite solution for 1 minute and washed in sterilized water for 3 minutes.

### 3.1.4 Seed

Seed of “Varuna” variety of mustard was obtained from ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur (Rajasthan) and "Ganga" variety of Nirmal Pvt. Ltd. was procured from Banda market, Uttar Pradesh, India.

### 3.1.5 Experimental site

Field experiments were conducted in the Agricultural Research Farm of the College of Agriculture, BUAT Banda (UP) during Rabi season 2018-19 and 2019-20 and laboratory work was done in the PG Lab. of Department of Plant Pathology, College of Agriculture, BUAT Banda (UP).

### 3.1.6 Test organism

Pathogen (*Alternaria brassicae*) was isolated from infected leaves of mustard from the crop grown in farm of the BUAT Banda using standard isolation procedure.

### 3.1.7 Nutrient media

Potato dextrose agar (PDA) and corn meal agar (CMA) media were used for isolation and maintenance of the pathogen. Composition of the PDA and CMA were as follows: -

PDA		CMA	
Peeled potatoes	200 g	Corn seeds	150 g
Dextrose	20 g	Dextrose	20 g
Agar- agar	20 g	Agar- agar	20 g
Distilled water	1000 ml	Distilled water	1000 ml

## 3.2 Methods

### 3.2.1 Symptomatology

Mustard trial fields were regularly visited during rabi 2018-19 and 2019-20 and symptoms of *Alternaria* blight disease was recorded on leaves, silique and stem of mustard

plants. These plant parts showing typical symptoms of *Alternaria* blight were collected and kept in sterile polyethylene bags. These samples were stored in a refrigerator for further use.

### **3.2.2 Media preparation**

Potato dextrose agar (PDA) media was prepared by boiling the 200 g peeled and chopped potatoes in 1000 ml of distilled water for 20 minutes till the potato become soft. Boiled solution was sieved by muslin cloth in sterilized measuring cylinder. Twenty gram of dextrose was added and dissolved and then 20 g agar-agar was added to make final volume of 1000 ml by adding distilled water and mixing it properly. The pH of the media was adjusted in range of 6.0 to 6.5. The media was poured in conical flasks and culture tubes (for slants) and plugged with non-absorbent cotton. Poured flasks and culture tubes were sterilized in autoclave at 121.6°C temperature at 15 psi pressure for a period of 20 minutes. After sterilization 30 ppm of streptomycin was added in media under sterilized conditions. Then the media was poured in sterilized Petri plates for isolation and other *in vitro* studies.

Corn meal agar (CMA) media was also used for isolation of the pathogen from infected plant parts. Same procedure was followed for preparation of CMA media as for PDA media preparation except for the use of corn seeds (150 g) instead of peeled potatoes.

### **3.2.3 Isolation and purification of the pathogen**

The infected leaves were collected from the mustard field in agricultural farm of College of Agriculture, BUAT Banda. Collected leaf samples were washed with distilled water. Leaf samples were cut into small pieces of 3 to 5 mm size with the sharp blade from healthy along with diseased portion inside a laminar air flow cabinet. Small bits with both diseased and healthy portion were moved through 1 % sodium hypochlorite solution for one minute for surface sterilization and washed three times with changed sterile distilled water. Bits were then kept on a sterile filter paper and aseptically 2-3 pieces were transfer in already poured Petri plate inside a laminar air flow cabinet and then incubated in BOD incubator at 25 ±1°C. After appearance of mycelial growth, the fungus was then transferred by taking hyphal tip onto a fresh media slant or poured Petri plate. Purification of the isolated fungus was

fulfilled using hyphal tip method and single spore isolation technique as described by Dhingra and Sinclair (1985).

#### **3.2.4 Identification of the pathogen**

Test pathogen was identified by taking a small tip from the pure culture on glass slide and seeing under microscope. On the basis of morphology of the isolated pathogen viz. shape, size and colour of conidia, beak, conidiophores, hyphae etc. and comparing with the literature (Simmons, 2007) the pathogen was identified as *Alternaria brassicae* (Berk.) Sacc.

#### **3.2.5 Pathogenicity test**

Pathogenicity of the pathogen was tested by confirming Koch's postulates. The seedlings of mustard variety Ganga were grown in plastic pots having 12 inches diameter and 7 days old pure culture of the pathogen was inoculated at 45 days after sowing by spraying the pathogen solution ( $10^4$  spore/ml) made by mixing the bits from the pure cultured Petri plates in sterile distilled water. Symptoms of the disease appeared in first week after inoculation. The fungus was re-isolated from the leaves showing symptoms of *Alternaria* blight and the culture was examined under microscope and confirmed as *Alternaria brassicae* in laboratory.

#### **3.2.6 Evaluation of oilseed brassica germplasm/ varieties against *Alternaria* blight**

Field trial for screening of 35 genotypes of SBG-18 and 61 genotypes of UDN-18 belonging to different species of Brassica was conducted in the Agricultural Research Farm of College of Agriculture, BUAT Banda (UP) in randomized block design (RBD) for source of resistance in the rabi season 2018-19 and 2019-20 (Table 2,3). Germplasm evaluated were received from the ICAR- DMR Bharatpur, Rajasthan under AICRP- Rapeseed-mustard project. Each germplasm/ variety was replicated two times. All germplasm were sown on 27<sup>th</sup> October during both the years in 3 meter long rows. One row of susceptible check (Varuna) was sown after each five rows. Five plants were randomly selected and tagged from each replication of each germplasm/ variety and investigated 100 days after sowing for collection of data on per cent disease index (PDI).

### 3.2.6.1 Observations recorded

The observations of disease reaction and PDI or disease severity were recorded by randomly selecting five plants from each genotype/ variety. Each selected plant was tagged and 15 leaves (5 lower, 5 middle and 5 upper parts of plants) were observed for disease reaction by putting and comparing with the 0-6 point scale given by Conn *et al.* (1990) as given in Table 1. Numerical rating grades were given on the basis of percentage of area covered by pathogen on the selected leaves. On the basis of disease intensity different lines were classified into different groups namely, immune, highly resistant, resistant, moderately resistant, susceptible and highly susceptible. Per cent disease index was calculated by using the formula given by McKinney (1923) as follows:

$$\text{Per cent Disease Index} = \frac{\text{Sum of all disease rating}}{\text{Total no. of disease rating} \times \text{maximum disease grade}} \times 100$$

**Table 1. Rating scale for assessment of Alternaria blight of mustard**

<b>Rating scale</b>	<b>Disease intensity (%) / Infection in leaf (% area)</b>	<b>Disease reaction</b>
0	No infection	Immune (I)
1	Up to 5 % area covered	Highly resistant (HR)
2	>5-10 % area covered	Resistant (R)
3	> 10-20 % area covered	Moderately resistant (MR)
4	> 20-30 % area covered	Moderately susceptible (MS)
5	>30-50 % area covered	Susceptible (S)
6	> 50 area covered	Highly susceptible (HS)

**Table 2. Germplasm/ varieties of various oilseed brassicas screened for resistance (SBG-18)**

<b>S. no.</b>	<b>Entries</b>	<b>S. no.</b>	<b>Entries</b>
1	SBG-18-1	19	SBG-18-19
2	SBG-18-2	20	SBG-18-20
3	SBG-18-3	21	SBG-18-21
4	SBG-18-4	22	SBG-18-22
5	SBG-18-5	23	SBG-18-23
6	SBG-18-6	24	SBG-18-24
7	SBG-18-7	25	SBG-18-25
8	SBG-18-8	26	SBG-18-26
9	SBG-18-9	27	SBG-18-27
10	SBG-18-10	28	SBG-18-28
11	SBG-18-11	29	SBG-18-29
12	SBG-18-12	30	SBG-18-30
13	SBG-18-13	31	SBG-18-31
14	SBG-18-14	32	SBG-18-32
15	SBG-18-15	33	SBG-18-33
16	SBG-18-16	34	SBG-18-34
17	SBG-18-17	35	SBG-18-35
18	SBG-18-18		

**Table 3. Germplasm/ varieties of various oilseed brassicas screened for resistance (UDN-18)**

<b>S. no</b>	<b>Entries</b>	<b>S. no.</b>	<b>Entries</b>
1	UDN-18-1	32	UDN-18-32
2	UDN-18-2	33	UDN-18-33
3	UDN-18-3	34	UDN-18-34
4	UDN-18-4	35	UDN-18-35
5	UDN-18-5	36	UDN-18-36
6	UDN-18-6	37	UDN-18-37
7	UDN-18-7	38	UDN-18-38
8	UDN-18-8	39	UDN-18-39
9	UDN-18-9	40	UDN-18-40

10	UDN-18-10	41	UDN-18-41
11	UDN-18-11	42	UDN-18-42
12	UDN-18-12	43	UDN-18-43
13	UDN-18-13	44	UDN-18-44
14	UDN-18-14	45	UDN-18-45
15	UDN-18-15	46	UDN-18-46
16	UDN-18-16	47	UDN-18-47
17	UDN-18-17	48	UDN-18-48
18	UDN-18-18	49	UDN-18-49
19	UDN-18-19	50	UDN-18-50
20	UDN-18-20	51	UDN-18-51
21	UDN-18-21	52	UDN-18-52
22	UDN-18-22	53	UDN-18-53
23	UDN-18-23	54	UDN-18-54
24	UDN-18-24	55	UDN-18-55
25	UDN-18-25	56	UDN-18-56
26	UDN-18-26	57	UDN-18-57
27	UDN-18-27	58	UDN-18-58
28	UDN-18-28	59	UDN-18-59
29	UDN-18-29	60	UDN-18-60
30	UDN-18-30	61	UDN-18-61
31	UDN-18-31		

### 3.2.7 Epidemiological studies

Effect of different weather parameters and different dates of sowing on severity of *Alternaria* blight was studied in field. The field trial was carried out at agricultural research farm of BUAT Banda with two susceptible variety of Indian mustard i.e. Varuna and Ganga during rabi season 2019-20. Both varieties were sown in 4 different dates at 7 days intervals (October 20<sup>th</sup>, 27<sup>th</sup>, November 03<sup>rd</sup>, and 10<sup>th</sup>) in split plot design with three replications in uniform plots of 5×1.5 m<sup>2</sup> size in which plant population with 30×10 cm<sup>2</sup> spacing was maintained. Basal dose of NPK @ 50:40:40 Kg/ha through urea, single super phosphate and muriate of potash, respectively was applied while remaining N @ 50 Kg/ha was applied as top dressing at first irrigation (30 days after sowing). No disease management measures were taken in contrast to any disease.

### 3.2.7.1 Effect of weather parameters on Alternaria blight of mustard

Effect of different weather parameters viz., average maximum and minimum temperature (°C), average morning, noon and evening relative humidity (%) and average rainfall (mm) on per cent disease index of Alternaria blight on Varuna and Ganga was studied by daily observing the field after the germination of the seeds for appearance of first symptom of the disease on leaves. After appearance of first symptoms the data on PDI was recorded every week till maturity of the crop.

PDI was calculated using the formula as described earlier in 3.2.6.1. Data on weather parameters was collected from the meteorological observatory of the BUAT Banda. Correlation coefficient (r), multiple regression equation and coefficient of determination (R<sup>2</sup>) was calculated using analysis software R to know the individual and combined effects of different weather parameters on PDI of Alternaria blight of Varuna and Ganga.

### 3.2.7.2 Effect of different dates of sowing on Alternaria blight of mustard

Effect of different dates of sowing was recorded by calculating the average PDI of the disease at weekly intervals starting from first appearance of symptom and average seed yield (q/ha) of Varuna and Ganga varieties of Indian mustard was weight at harvest in all the four sowing dates. Seed yield (q/ha) of individual plot was recorded after manually harvesting and threshing every treatment plots. Individual plot yield was then converted into per ha yield.

#### 3.2.7.2.1 Area under disease progress curve (AUDPC)

Disease progress curve was plotted by pointing the PDI of Alternaria blight disease on the Y- axis and time intervals of observations on the X- axis. AUDPC was obtained by plotting the area between curve and the X- axis to know the comparative effect of different sowing dates on progress of the disease using the formula given by Wilcoxson *et al.* (1975).

$$AUDPC = \sum_{i=1}^{n-1} \left( \frac{y_i + y_{i+1}}{2} \right) (t_{i+1} - t_i)$$

Where “t” is the time of each reading, “y” is the PDI at each reading and “n” is the number of readings.

### 3.2.8 Management studies

#### 3.2.8.1 *In vitro* evaluation of systemic and combination fungicides against *A. brassicae*

Six different systemic and combination fungicides viz., propiconazole 25% EC (Vijeta), azoxystrobin 23% SC (Mirador), hexaconazole 5% EC (Contaf), carbendazim 12% + mancozeb 63% WP (Crossman), captan 70% + hexaconazole 5% WP (Taqat) and metalaxyl 8% + mancozeb 64% WP (Matco) were evaluated *in vitro* against *A. brassicae* at four different concentrations i.e. 100, 250, 500 and 1000 ppm.

Evaluation under *in vitro* conditions was done through poisoned food technique (Falck, 1907) in which double strength PDA medium was prepared by doubling the amount of all the constituents except distilled water. The medium was sterilized at 15 psi pressure for 20 minutes. Simultaneously, double concentrations of different fungicides were also prepared in sterilized distilled water so as to get desired concentration of fungicides after mixing the fungicide solutions in the double strength media in equal amount before pouring in sterilized Petri plates. Approximately 25 ml of the medium containing test fungicide solution was poured in each sterilized Petri plate under aseptic condition in laminar air flow chamber. Each cooled plate was then inoculated with the seven days old culture of *A. brassicae* by transferring 5 mm mycelium discs cut with the help of cork borer. Control treatment was maintained by adding plain sterilized distilled water only to double strength medium. Each treatment was replicated thrice in Completely Randomized Design (CRD) and the inoculated plates were incubated at  $25 \pm 1^\circ\text{C}$  in BOD incubator. Colony diameter of all the cultured plates were recorded when control plates acquired full growth with mycelium of the pathogen. The per cent mycelial growth inhibition of the pathogen was calculated according to formula given by Vincent (1947).

$$\text{Mycelial growth inhibition (\%)} = \frac{C - T}{C} \times 100$$

Where,

C - Linear mycelial growth in control (mm)

T - Linear mycelial growth in treatment (mm)

### **3.2.8.2 *In vitro* evaluation of non-systemic fungicides against *A. brassicae***

A total of three different non-systemic fungicides viz., mancozeb 75% WP (Indofil M-45), propineb 70% WP (Antracol) and wettable sulphur 90% DP (Diamond) were evaluated under *in vitro* conditions against the *A. brassicae* at 250, 500, 1000 and 2000 ppm concentrations through poisoned food technique as described in 3.2.8.1. Each treatment was replicated thrice under Completely Randomized Design.

### **3.2.8.3 *In vivo* evaluation of fungicides against Alternaria blight of mustard**

All nine systemic, combination and non-systemic fungicides were also tested *in vivo* for their efficacy against Alternaria blight disease at recommended concentrations as follows: propiconazole 25% EC (Vijeta), azoxystrobin 23% SC (Mirador), hexaconazole 5% EC (Contaf) and captan 70% + hexaconazole 5% WP (Taqat) @ 0.1%; carbendazim 12% + mancozeb 63% WP (Crossman), metalaxyl 8% + mancozeb 64% WP (Matco) and propineb 70% WP (Antracol) @ 0.2%; mancozeb 75% WP (Indofil M-45), and wettable sulphur 90% DP (Diamond) @ 0.25% whereas, control treatment was left unsprayed with any fungicide.

The experiment was conducted in the agricultural research farm of BUAT Banda during rabi 2019-20. Basal dose of NPK @ 50:40:40 Kg/ha through urea, single super phosphate and muriate of potash, respectively was applied while remaining N @ 50 Kg/ha was applied as top dressing at first irrigation (30 days after sowing). Indian mustard variety 'Ganga' was sown on 20<sup>th</sup> October 2019. All six systemic and combi-fungicides were sprayed once at 60 DAS and three non-systemic fungicides were applied with two sprays at 15 days interval with 1<sup>st</sup> spray at 60 DAS. Plot sizes of 5×3 m<sup>2</sup> in dimensions were maintained for each treatment and each treatment was replicated three times in a Randomized Block Design (RBD).

Disease severity (%) in form of Per cent disease index of Alternaria leaf blight was observed at 100 days after sowing. PDI was calculated as described earlier in 3.2.6.1. Per cent disease control was calculated as follows

$$\text{Disease control (\%)} = \frac{\text{Incidence in control (\%)} - \text{Incidence in treatment (\%)}}{\text{Incidence in control (\%)}} \times 100$$

Seed yield (q/ha) of individual plot was recorded after manually harvesting and threshing every treatment plots. Individual plot yield was then converting into per ha yield.

### **3.2.9 Statistical analysis**

The data obtained during the study from various *in vitro* and field experiments were subjected to statistical analysis. The differences exhibited by treatments in various experiments were tested for their significance at 5 per cent using standard procedure as described by Gomez and Gomez (1983).

## **EXPERIMENTAL FINDINGS**

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The results obtained during the course of present investigation are being presented here as under:

### **4.1 Symptomatology**

Symptoms of the *Alternaria* blight of mustard appeared on lower leaves of the plant as black point sized necrotic spots, which later enlarged and developed into several sized round spots with concentric rings. Most of the spots were dark brownish with distinct grayish centres. After few days the disease also occurred on the middle and upper leaves. Small, black coloured and round shaped conspicuous spots appeared on the siliquae. Blister like symptoms were also seen on the siliquae. Various spots coalesce together leading to complete blackening and chlorosis resulting in defoliation of leaves and rotting of siliquae. Symptoms of *Alternaria* blight disease also appeared on the stem under severe conditions as purple to black coloured spots which weakened the affected stem of the plants (Plate 1).

### **4.2 Isolation and Purification**

*Alternaria brassicae* was isolated in pure culture from the affected leaves of mustard plant in potato dextrose agar and corn meal agar media by hyphal tip method. After inoculation and incubation, mycelial growth emerged from the diseased tissue on the poured Petri plates were initially white then olivaceous green/ light black to brown coloured in PDA and depressed mycelial growth with olivaceous to light black coloured colonies in CMA medium (Plate 2). Pathogen was purified through single spore technique and transferred in fresh slants containing CMA and PDA media. For further studies of *A. brassicae*, sub-culturing at 30 days interval were done and maintained in the refrigerator at 4°C temperature.



**a) Alternaria blight symptoms on the leaves**



**b) Alternaria blight symptoms on pods**

**c) Alternaria blight symptoms on the stem**

**Plate 1. Symptoms on leaves (a); pods (b); stem (c) of Alternaria blight of mustard**

### **4.3 Identification**

Identification of *Alternaria brassicae* was done by examining the pathogen under microscope that revealed mycelium was septate, branched, light brown to dark brown in colour. Most of conidia of *A. brassicae* were attached in 2-3 in chains. Conidia were borne singly from apex of conidiophores and were large, light to dark olivaceous to brown coloured, septate with 5-12 transverse and 0-4 longitudinal septa, obclavate and muriform in shape having prominent long beak which was pale brown and nearly cylindrical shaped (Plate 2).

### **4.4 Pathogenicity test**

Pathogenicity test of Alternaria blight was conducted by spraying the inoculum of *A. brassicae* @  $10^4$  spores/ml on the leaves of healthy plants grown in pots as described in Materials and Methods (3.2.5). The pot plants were regularly observed for initiation of first symptom of Alternaria blight. Pinhead sized brown to black coloured symptoms appeared on the leaves nearly after 120 hrs after pathogen inoculation. These symptoms were same as recorded in the plant from which the pathogen was isolated. Pathogen was re-isolated from the infected pot plants and after again examining under the microscope the morphological characters like shape, size and colour of the conidia reported same as earlier cultured *Alternaria brassicae*.

### **4.5 Screening of germplasm**

Screening of oilseed brassicas varieties/lines experiment conducted at agricultural research farm of Banda University of Agriculture and Technology, Banda during two rabi seasons 2018-19 and 2019-20 under natural conditions (Plate 3).

A total of 35 germplasm of SBG-18 and 61 germplasm of UDN-18 were screened in which a total of three germplasm of SBG-18 (25, 26, and 28) and one germplasm of UDN-18 (1) did not germinated. In SBG-18 PDI ranged from 6.04-67.32% during 2018-19 and 6.83-54.51% in 2019-20 whereas, in UDN-18 PDI ranged from 9.13-55.78% during 2018-19 and 5.97- 42.97% in 2019-20 (Table 4, 5).



**a) Pure culture of *Alternaria brassicae***



(i)



(ii)

**b) Conidia of *Alternaria brassicae*, (i), (ii)**



**c) Mycelium of *Alternaria brassicae***

**Plate 2. Pure culture (a), conidia (b) and mycelium (c) of *Alternaria brassicae***

Screened germplasm were also grouped into different disease reactions as per the assessment keys in Table 1.

Out of the 32 germplasm of SBG-18, no germplasm was found to be immune or highly resistant (Table 6, Fig. 1), one germplasm was found as resistant (SBG-18-29), five germplasm were moderately resistant SBG-18-4, 12, 13, 14 and 15, one germplasm was moderately susceptible (SBG-18-31), 17 germplasm were susceptible (SBG-18-1, 3, 5, 6, 7, 8, 9, 10, 16, 18, 20, 21, 23, 30, 33, 34 and 35) and 8 germplasm were highly susceptible (SBG-18-2, 11, 17, 19, 22, 24, 27 and 32).

Out of 60 germinated genotypes of the UDN-18 series none was found as immune or highly resistant (Table 7, Fig. 2), whereas, two germplasm were found as resistant (UDN-18-44, 51), two germplasm were moderately resistant (UDN-18-2 and 8), eight germplasm were moderately susceptible (UDN-18-9, 15, 18, 47, 50, 52, 54 and 57), 47 germplasm were found as susceptible (UDN-18-3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 48, 49, 53, 55, 56, 58, 59, 60 and 61) and one germplasm was found as highly susceptible (UDN-18-35).

**Table 4. Screening of oilseed brassicas germplasm (SBG-18-1 to 35)**

Germplasm /lines	Per cent disease index		
	2018-19	2019-20	Pooled
SBG-18-1	42.89 (40.89)	39.38 (38.85)	41.13 (39.87)
SBG-18-2	49.69 (44.80)	50.43 (45.23)	50.06 (45.01)
SBG-18-3	46.97 (43.24)	34.80 (36.11)	40.88 (39.68)
SBG-18-4	18.18 (25.19)	19.93 (26.49)	19.05 (25.84)
SBG-18-5	39.32 (38.81)	34.42 (35.87)	36.87 (37.34)
SBG-18-6	53.63 (47.06)	44.09 (41.58)	48.86 (44.32)
SBG-18-7	37.58 (37.77)	30.52 (33.52)	34.05 (35.64)
SBG-18-8	54.13 (47.36)	44.89 (42.04)	49.51 (44.70)
SBG-18-9	48.68 (44.22)	46.10 (42.74)	47.39 (43.48)
SBG-18-10	47.22 (43.38)	31.77 (34.27)	39.49 (38.82)
SBG-18-11	61.54 (51.65)	46.58 (43.02)	54.06 (47.33)
SBG-18-12	20.28 (26.75)	15.25 (22.97)	17.77 (24.86)
SBG-18-13	15.56 (23.19)	10.04 (18.46)	12.80 (20.83)
SBG-18-14	25.48 (30.30)	19.87 (26.44)	22.67 (28.37)
SBG-18-15	16.47 (23.93)	14.10 (22.04)	15.28 (22.99)

SBG-18-16	47.03 (43.27)	42.00 (40.34)	44.51 (41.81)
SBG-18-17	67.32 (55.12)	53.31 (46.88)	60.31 (51.00)
SBG-18-18	52.38 (46.34)	46.43 (42.93)	49.40 (44.64)
SBG-18-19	60.31 (50.24)	51.59 (45.89)	55.94 (48.41)
SBG-18-20	47.60 (43.60)	42.46 (40.61)	45.03 (42.11)
SBG-18-21	54.50 (47.56)	44.86 (42.03)	49.68 (44.79)
SBG-18-22	62.34 (52.13)	53.85 (47.19)	58.09 (49.66)
SBG-18-23	46.30 (42.85)	45.94 (42.65)	46.12 (42.75)
SBG-18-24	54.41 (47.51)	53.20 (46.81)	53.80 (47.16)
SBG-18-27	52.52 (46.43)	54.51 (47.50)	53.52 (47.01)
SBG-18-29	06.04 (14.22)	06.83 (15.13)	06.43 (14.68)
SBG-18-30	54.29 (47.44)	44.35 (41.74)	49.32 (44.59)
SBG-18-31	22.49 (28.24)	25.70 (30.45)	24.10 (29.34)
SBG-18-32	58.36 (49.79)	50.34 (45.17)	54.35 (47.48)
SBG-18-33	40.50 (39.51)	36.93 (37.41)	38.72 (38.46)
SBG-18-34	37.14 (37.53)	36.38 (37.05)	36.76 (37.29)
SBG-18-35	46.55 (43.00)	40.20 (39.33)	43.37 (41.16)

Figures in parentheses are angular transformed values

	<b>C.D.</b>	<b>SE<sub>(m)</sub></b>
Germplasm	2.98	1.05
Year	0.74	0.26
Germplasm × Year	4.22	1.49

**Table 5. Screening of oilseed brassicas germplasm (UDN-18-1 to 61)**

Germplasm/lines	Per cent disease index		
	2018-19	2019-20	Pooled
UDN-18-2	11.41 (19.73)	10.85 (19.22)	11.13 (19.48)
UDN-18-3	39.34 (38.83)	25.67 (30.38)	32.50 (34.60)
UDN-18-4	32.78 (34.91)	22.07 (28.01)	27.43 (31.47)
UDN-18-5	28.21 (32.06)	21.05 (27.29)	24.63 (29.68)
UDN-18-6	29.81 (33.07)	22.16 (28.07)	25.98 (30.57)
UDN-18-7	29.92 (33.13)	22.47 (28.28)	26.20 (30.71)
UDN-18-8	15.56 (23.22)	13.77 (21.77)	14.67 (22.49)
UDN-18-9	25.73 (30.46)	18.85 (25.66)	22.29 (28.07)
UDN-18-10	33.60 (35.39)	20.16 (26.64)	26.88 (31.02)
UDN-18-11	31.07 (33.84)	29.28 (32.74)	30.18 (33.29)
UDN-18-12	29.76 (33.01)	23.66 (29.06)	26.71 (31.05)
UDN-18-13	37.96 (38.00)	22.23 (28.12)	30.10 (33.07)
UDN-18-14	38.95 (38.59)	31.54 (34.15)	35.25 (36.38)
UDN-18-15	27.85 (31.82)	21.69 (27.69)	24.77 (29.76)
UDN-18-16	30.31 (33.37)	30.18 (33.30)	30.25 (33.35)
UDN-18-17	38.38 (38.26)	24.07 (29.36)	31.23 (33.81)
UDN-18-18	27.89 (31.86)	28.99 (32.56)	28.45 (32.22)

UDN-18-19	42.60 (40.73)	38.05 (38.07)	40.33 (39.42)
UDN-18-20	37.79 (37.92)	31.29 (33.99)	34.54 (35.96)
UDN-18-21	30.09 (33.24)	25.55 (30.35)	27.82 (31.79)
UDN-18-22	39.96 (39.19)	33.30 (35.22)	36.63 (37.22)
UDN-18-23	39.22 (38.75)	30.89 (33.71)	35.06 (36.24)
UDN-18-24	39.73 (39.04)	32.63 (34.82)	36.19 (36.93)
UDN-18-25	38.98 (38.58)	33.15 (35.13)	36.07 (36.85)
UDN-18-26	34.65 (36.04)	30.33 (33.40)	32.50 (34.72)
UDN-18-27	35.16 (36.35)	30.86 (33.73)	33.02 (35.04)
UDN-18-28	38.27 (38.21)	27.47 (31.59)	32.87 (34.90)
UDN-18-29	37.51 (37.75)	36.89 (37.38)	37.20 (37.56)
UDN-18-30	46.76 (43.12)	42.97 (40.94)	44.86 (42.04)
UDN-18-31	30.82 (33.71)	19.91 (26.43)	25.37 (30.07)
UDN-18-32	29.98 (33.18)	22.84 (28.54)	26.41 (30.86)
UDN-18-33	46.68 (43.08)	37.44 (37.70)	42.07 (40.40)
UDN-18-34	42.42 (40.62)	34.04 (35.67)	38.24 (38.16)
UDN-18-35	55.78 (48.30)	27.45 (31.56)	41.61 (39.93)
UDN-18-36	42.61 (40.73)	36.54 (37.18)	39.57 (38.95)
UDN-18-37	33.44 (35.27)	22.35 (28.20)	27.87 (31.74)
UDN-18-38	30.04 (33.22)	28.50 (32.25)	29.27 (32.73)
UDN-18-39	48.96 (44.38)	39.64 (39.00)	44.30 (41.69)
UDN-18-40	29.25 (32.72)	19.47 (26.17)	24.36 (29.45)
UDN-18-41	33.28 (35.22)	25.93 (30.56)	29.61 (32.89)
UDN-18-42	33.64 (35.43)	25.94 (30.60)	29.79 (33.03)
UDN-18-43	35.20 (36.37)	22.72 (28.45)	28.96 (32.42)
UDN-18-44	10.98 (19.34)	09.36 (17.79)	10.18 (18.57)
UDN-18-45	36.20 (36.93)	29.47 (32.82)	32.83 (34.87)
UDN-18-46	09.13 (17.57)	05.97 (14.31)	07.54 (15.85)
UDN-18-47	23.97 (29.30)	19.57 (26.24)	21.77 (27.77)
UDN-18-48	38.43 (38.27)	35.60 (36.55)	37.02 (37.42)
UDN-18-49	33.89 (35.57)	23.08 (28.64)	28.48 (32.11)
UDN-18-50	24.65 (29.68)	23.04 (28.67)	23.84 (29.18)
UDN-18-51	10.09 (18.50)	07.82 (16.32)	08.95 (17.37)
UDN-18-52	16.43 (23.89)	16.20 (23.72)	16.32 (23.81)
UDN-18-53	30.17 (33.30)	26.80 (31.11)	28.49 (32.21)
UDN-18-54	26.84 (31.19)	22.47 (28.22)	24.65 (29.70)
UDN-18-55	43.86 (41.45)	42.67 (40.76)	43.27 (41.11)
UDN-18-56	35.54 (36.57)	30.73 (33.65)	33.14 (35.12)
UDN-18-57	26.68 (31.06)	27.11 (31.35)	26.89 (31.22)
UDN-18-58	38.55 (38.36)	28.23 (32.08)	33.40 (35.23)
UDN-18-59	34.66 (36.02)	34.01 (35.66)	34.34 (35.84)
UDN-18-60	28.84 (32.47)	21.26 (27.41)	25.06 (29.94)
UDN-18-61	40.72 (39.63)	33.30 (35.21)	37.02 (37.43)

Figures in parenthesis are angular transformed values

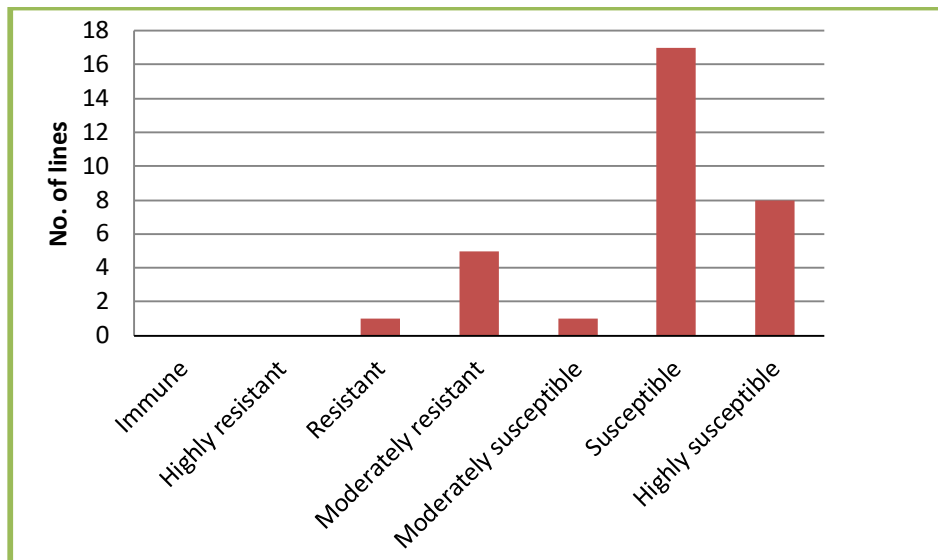
	<b>C.D.</b>	<b>SE<sub>(m)</sub></b>
Germplasm	2.29	0.81
Year	0.41	0.14
Germplasm × Year	3.24	1.15

**Table 6. Reaction of oilseed brassicas germplasm (SBG-18) against Alternaria blight**

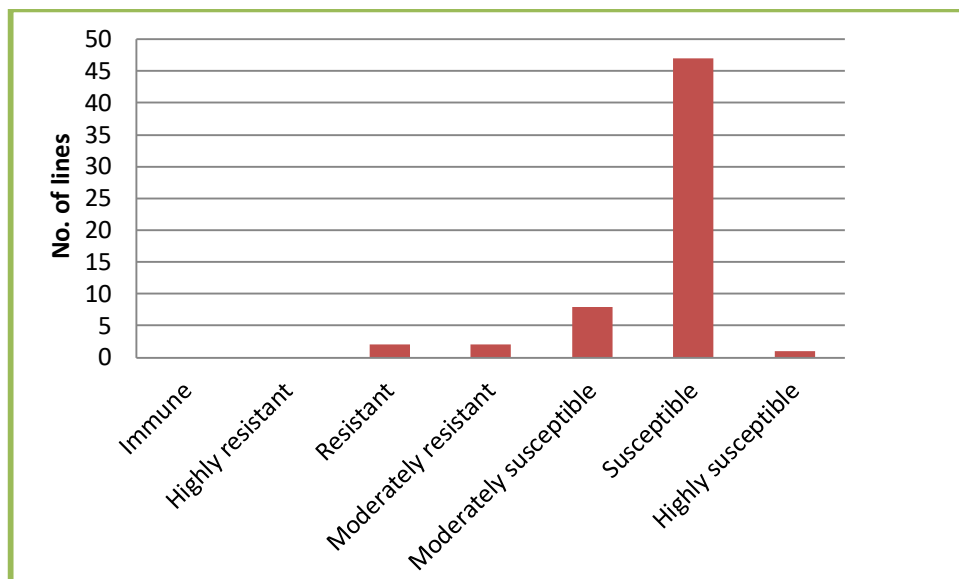
Scale	Disease reaction	SBG-18 disease reaction on the basis of Pooled PDI (2018-19 & 2019-20)	
		Number	Name of germplasm
0	Immune	-	-
1	Highly resistant	-	-
2	Resistant	1	SBG-18-29
3	Moderately resistant	5	SBG-18-4, 12, 13, 14 and 15
4	Moderately susceptible	1	SBG-18-31
5	Susceptible	17	SBG-18-1, 3, 5, 6, 7, 8, 9, 10, 16, 18, 20, 21, 23, 30, 33, 34 and 35
6	Highly susceptible	8	SBG-18-2, 11, 17, 19, 22, 24, 27 and 32

**Table 7. Reaction of oilseed brassicas germplasm (UDN-18) against Alternaria blight**

Scale	Disease reaction	UDN-18 disease reaction on the basis of Pooled PDI (2018-19 & 2019-20)	
		Number	Name of germplasm
0	Immune	-	-
1	Highly resistant	-	-
2	Resistant	2	UDN-18-46, 51
3	Moderately resistant	2	UDN-18-2 and 8
4	Moderately susceptible	8	UDN-18-9, 15, 18, 47, 50, 52, 54 and 57
5	Susceptible	47	UDN-18-3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 48, 49, 53, 55, 56, 58, 59, 60 and 61
6	Highly susceptible	1	UDN-18-35



**Figure 1. Reaction of oilseed brassicas germplasm (SBG-18) against Alternaria blight**



**Figure 2. Reaction of oilseed brassicas germplasm (UDN-18) against Alternaria blight**



**Field of screening trial**



**a) SBG-18-29**



**b) SBG-18-13**



**c) SBG-18-12**

**Plate 3. Screening of SBG-18 and UDN- 18 germplasm**

## **4.6 Epidemiological studies**

Effect of different weather parameters and different dates of sowing on severity of Alternaria blight was studied in field. The field trial was carried out at agricultural research farm of Banda University of Agriculture and Technology, Banda with two susceptible variety of Indian mustard i.e. Varuna and Ganga during rabi season 2019-20. Both varieties were sown in 4 different dates at 7 days interval i.e. on October 20<sup>th</sup>, 27<sup>th</sup>, November 03<sup>rd</sup> and 10<sup>th</sup>, 2019.

### **4.6.1 Effect of weather parameters on Alternaria blight of mustard**

Effect of different weather parameters viz., average maximum and minimum temperature (°C), average morning, noon and evening relative humidity (%) and average rainfall (mm) on per cent disease index of Alternaria blight on Varuna and Ganga sown on 20<sup>th</sup> October 2019 was studied by daily observing the field after the germination of the seeds for appearance of first symptom of the disease on leaves. After appearance of first symptoms the data on PDI was recorded every week till maturity of the crop.

It is evident from the Table 8 that during growing period of the crop the weekly average maximum temperature ranged from 18-30.57°C and weekly average minimum temperature ranged from 6.43-18.71°C. Weekly average RH during morning, noon and evening was ranging from 81.86-94.71%, 31.57-63.57% and 58.14-80.57%, respectively. Rainfall of 19.2 mm was received during 8<sup>th</sup> week after sowing and during 13<sup>th</sup> week after the sowing 19.1 mm rainfall was recorded.

Perusal of data in Table 8 also clearly depicts that the first symptom of Alternaria blight in Varuna and Ganga appeared in 49<sup>th</sup> meteorological week i.e. eight weeks after sowing during which the maximum average temperature recorded was 22.14°C, minimum average temperature was 10.29°C, average morning RH was 91.57%, average noon RH was 60.57%, average evening RH was 80.57% and total weekly rainfall of 19.2 mm was received. Rainfall of 19.2 mm in 8<sup>th</sup> week prolonged the leaf wetness hours which along with favourable temperature and >90% average morning RH might have provided the congenial environmental

conditions for infection of *Alternaria brassicae* on mustard leaves. After 8<sup>th</sup> sowing week disease severity increased gradually and risen exponentially 13<sup>th</sup> week after sowing in which 19.1 mm rainfall was received. The highest disease severity was observed in 16<sup>th</sup> week in which average weekly maximum temperature was 23.57°C with >80% average morning RH and thereafter remained static as most of the lower and middle leaves were fallen off due to the disease infection (Fig. 3, 4).

**Table 8. Effect of weather parameters on Alternaria blight of mustard**

<b>Weks after sowing</b>	<b>Meteorologic week</b>	<b>PDI Varuna</b>	<b>PDI Gang a</b>	<b>Maximum Temp (°C)</b>	<b>Minimum Temp (°C)</b>	<b>RH Morning (%)</b>	<b>RH Noon (%)</b>	<b>RH Evening (%)</b>	<b>Rainfall (mm)</b>
1	42 <sup>nd</sup>	0.00	0.00	30.57	18.71	90	55	73.14	0.00
2	43 <sup>rd</sup>	0.00	0.00	29.71	18.00	85.14	36.86	67.71	0.00
3	44 <sup>th</sup>	0.00	0.00	30.14	16.29	82.14	34	65.14	0.00
4	45 <sup>th</sup>	0.00	0.00	27.29	15.86	85.14	32.29	64.29	0.00
5	46 <sup>th</sup>	0.00	0.00	27.00	14.57	84.57	34.29	65.43	0.00
6	47 <sup>th</sup>	0.00	0.00	25.00	13.86	86	45.29	69.43	0.00
7	48 <sup>th</sup>	0.00	0.00	24.00	11.29	86	36.71	63.57	0.00
8	49 <sup>th</sup>	0.92	0.81	22.14	10.29	91.57	60.57	80.57	19.2
9	50 <sup>th</sup>	1.84	1.59	22.21	10.31	91.57	48.71	76.43	0.00
10	51 <sup>st</sup>	2.67	2.42	18.00	6.43	93.43	52.14	79.43	0.00
11	52 <sup>nd</sup>	3.37	3.7	19.71	6.79	94.71	63.57	84.14	0.00
12	1 <sup>st</sup>	6.97	6.07	21.43	7.00	89.29	60.0	76.57	0.00
13	2 <sup>nd</sup>	12.29	12.13	20.43	7.31	89.71	54.29	75.0	19.1
14	3 <sup>rd</sup>	26.92	21.85	22.14	9.43	87.57	41.57	66.29	0.00
15	4 <sup>th</sup>	47.18	43.85	22.41	11.86	85.0	36.14	62.71	0.00
16	5 <sup>th</sup>	49.62	47.56	23.57	13.89	81.86	38.71	60.43	0.00
17	6 <sup>th</sup>	49.62	47.56	24.29	14.97	83.71	31.57	58.14	0.00

To know the dependency of disease severity of Alternaria blight on different recorded parameters correlation and regression between them was evaluated, in which per cent disease index of Alternaria blight of mustard was positively correlated with the average minimum temperature whereas, it was significantly negative correlated with the average evening relative humidity in both the varieties. PDI of Alternaria blight was recorded negatively correlated with all other weather parameters in both the varieties (Table 9, Fig. 5).

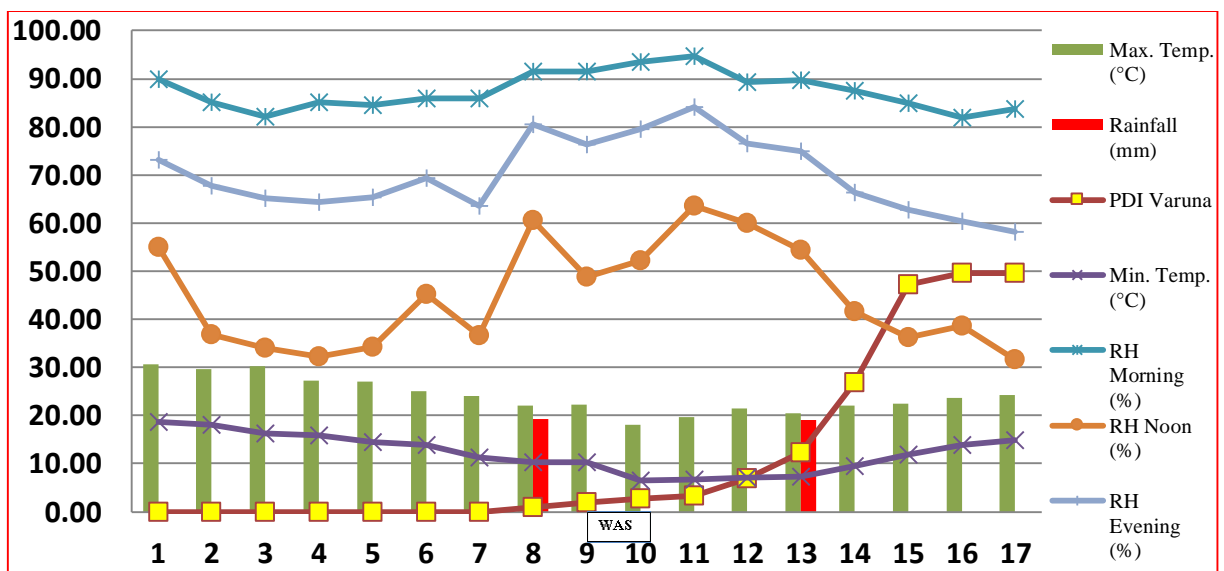


Figure 3. Effect of weather parameters on Alternaria blight of mustard (Varuna)

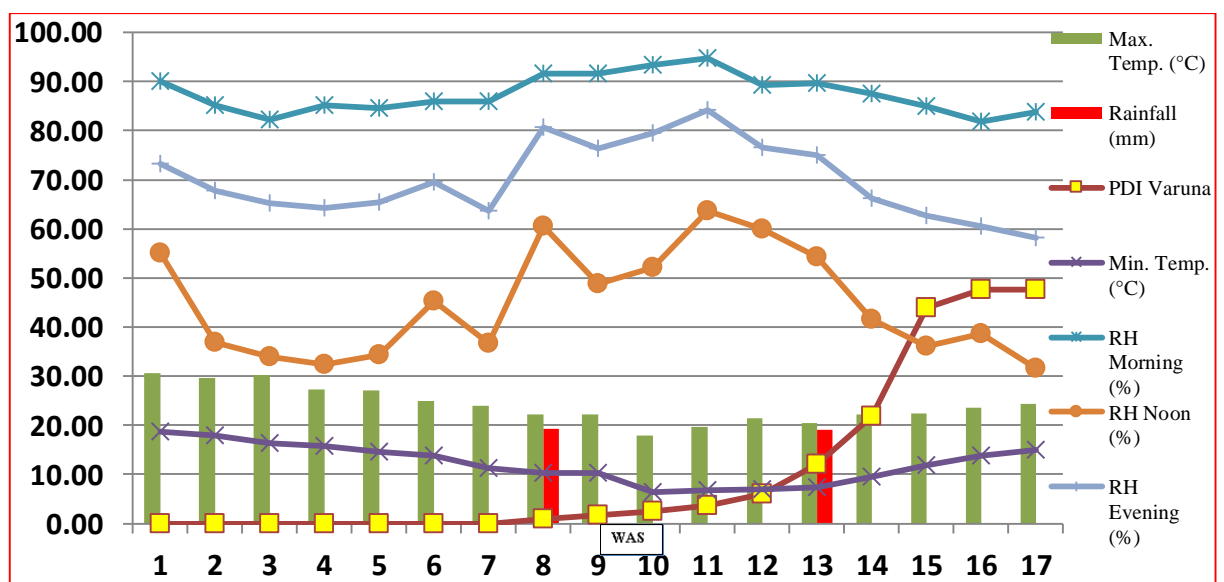


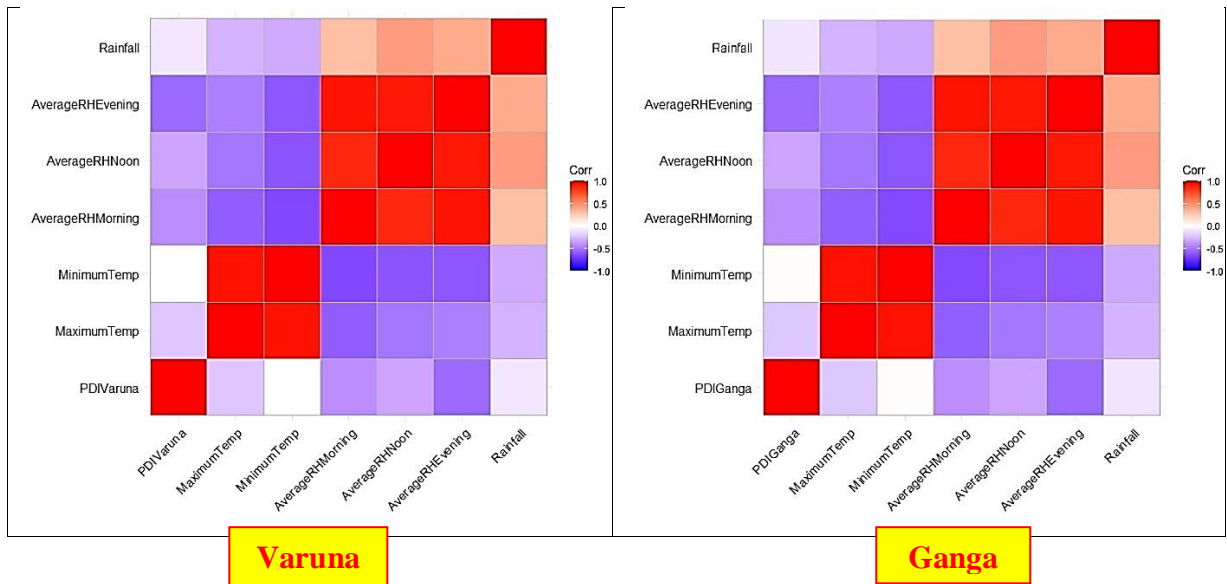
Figure 4. Effect of weather parameters on Alternaria blight of mustard (Ganga)

**Table 9. Correlation coefficient between PDI of Alternaria blight and weather parameters**

Weather parameters	Correlation coefficient “r”	
	PDI (Varuna)	PDI (Ganga)
MaximumTemp.	-0.226	-0.221
MinimumTemp.	0.002	0.012
RHMorning	-0.420	-0.424
RHNoon	-0.342	-0.340
RHEvening	-0.555*	-0.553*
Rainfall	-0.105	-0.097

\*Significant at 5% level

It is evident from the Table 10 that on multiple regression analysis of the PDI of Alternaria blight with different weather parameters that regression coefficient was significant at 5% level with Maximum Temp. and RH Noon whereas, it was significant with Minimum Temp. and RH Evening at 1% level for both Varuna and Ganga.



**Figure 5. Thermal diagram of correlation between PDI of Alternaria blight and weather parameters**

Multiple regression analysis was also performed to know the combined effect of different weather parameters. Coefficient of Determination ( $R^2$ ) of 0.812 was calculated in Varuna which implies that all the weather parameters were 81.2 per cent associated for PDI of Alternaria blight and rest 18.8 per cent of the disease was due to the response of some other factors. Multiple regression equation was formulated for PDI in Varuna as:

$$\text{PDI Varuna} = 363.8743 - 7.4097 (\text{Max. Temp.}) + 4.7825 (\text{Min. Temp.}) - 0.9605 (\text{RH Morning}) + 1.5191 (\text{RH Noon}) - 3.0791 (\text{RH Evening}) - 0.1212 (\text{Rainfall})$$

Coefficient of Determination ( $R^2$ ) of 0.818 was calculated in Ganga which implies that all the weather parameters were 81.8 per cent associated for PDI of Alternaria blight and rest 18.2 per cent of the disease was due to the response of some other factors. Multiple regression equation was formulated for PDI in Ganga as:

$$\text{PDI Ganga} = 358.5896 - 7.3655 (\text{Max. Temp.}) + 4.9141 (\text{Min. Temp.}) - 1.1693 (\text{RH Morning}) + 1.4290 (\text{RH Noon}) - 2.7350 (\text{RH Evening}) - 0.1014 (\text{Rainfall})$$

**Table 10 Regression coefficient of PDI of Alternaria blight and weather parameters**

Weather parameter	Regression coefficient (P-value)	
	Varuna	Ganga
Max. Temp.	0.02*	0.01*
Min. Temp.	0.08**	0.06**
RH Morning	0.67	0.58
RH Noon	0.05*	0.04*
RH Evening	0.06**	0.07**
Rainfall	0.80	0.81

\*Significant at 5% level

\*\*Significant at 1% level

#### 4.6.2 Effect of different dates of sowing on Alternaria blight of mustard

Effect of different dates of sowing on PDI of the Alternaria blight at weakly intervals starting from first appearance of symptom and average yield (q/ha) of Varuna and Ganga varieties of Indian mustard at harvest in all the four sowing dates (20.10.19; 27.10.19; 03.11.19; 10.11.19) were evaluated.

**Table 11. Per cent disease index of Alternaria blight on mustard leaves at different dates of sowing**

Week after sowing (WAS)	Per cent disease index (PDI) on different dates of sowing										Overall mean
	Varuna					Ganga					
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	Mean	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	Mean	
5 WAS	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.05 (5.87)	0.26 (1.47)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.68 (4.54)	0.17 (1.14)	0.22 (1.30)
6 WAS	0.00 (0.00)	0.00 (0.00)	1.10 (5.91)	2.02 (8.16)	0.78 (3.58)	0.00 (0.00)	0.00 (0.00)	0.37 (3.47)	1.99 (8.11)	0.59 (2.89)	0.68 (3.20)
7 WAS	0.00 (0.00)	0.74 (4.94)	1.36 (6.67)	2.99 (9.90)	1.27 (5.38)	0.00 (0.00)	1.03 (5.80)	1.07 (5.92)	2.92 (9.82)	01.26 (5.39)	1.27 (5.39)
8 WAS	0.92 (5.49)	1.69 (7.49)	2.34 (8.77)	4.35 (12.03)	2.32 (8.45)	0.81 (5.15)	1.60 (7.26)	2.0 (8.12)	3.86 (11.34)	2.07 (7.96)	2.20 (8.20)
9 WAS	1.84 (7.76)	2.69 (9.45)	5.18 (13.13)	6.87 (15.19)	4.15 (11.38)	1.59 (7.23)	2.59 (9.26)	3.14 (10.21)	6.57 (14.83)	3.47 (10.38)	3.81 (10.88)
10 WAS	2.67 (9.39)	4.34 (12.01)	6.13 (14.32)	10.78 (19.11)	5.98 (13.70)	2.42 (8.93)	3.66 (11.02)	4.11 (11.67)	10.17 (18.53)	5.09 (12.54)	5.53 (13.12)
11 WAS	3.36 (10.56)	5.78 (13.90)	11.20 (19.20)	26.22 (30.77)	11.64 (18.61)	3.70 (11.06)	5.85 (13.98)	10.74 (19.11)	20.17 (26.66)	10.11 (17.70)	10.88 (18.16)
12 WAS	6.96 (15.24)	15.30 (23.01)	22.99 (28.54)	43.44 (41.22)	22.17 (27.00)	6.07 (14.25)	11.18 (19.44)	23.37 (28.89)	37.28 (37.61)	19.48 (25.05)	20.82 (26.02)
13 WAS	12.30 (20.47)	26.59 (31.03)	49.66 (44.78)	49.16 (44.50)	34.43 (35.20)	12.13 (20.36)	23.33 (28.86)	48.15 (43.91)	48.00 (43.83)	32.90 (34.24)	33.66 (34.72)
14 WAS	26.92 (31.25)	51.34 (45.74)	58.37 (49.79)	55.39 (48.08)	48.00 (43.72)	21.85 (27.81)	48.40 (44.07)	56.63 (48.79)	53.16 (46.79)	45.01 (41.87)	46.51 (42.79)
15 WAS	47.18 (43.37)	56.48 (48.70)	58.37 (49.79)	56.39 (48.65)	54.60 (47.63)	43.85 (41.44)	54.92 (47.80)	57.26 (49.16)	54.16 (47.37)	52.55 (46.44)	53.58 (47.04)
16 WAS	49.62 (44.76)	56.48 (48.70)	58.37 (49.79)	56.39 (48.65)	55.21 (47.98)	47.56 (43.58)	54.92 (47.80)	57.26 (49.16)	54.16 (47.37)	53.47 (46.978)	54.34 (47.48)
17 WAS	49.62 (44.76)	56.48 (48.70)	58.37 (49.79)	56.39 (48.65)	55.21 (47.98)	47.56 (43.58)	54.92 (47.80)	57.26 (49.16)	54.16 (47.37)	53.47 (46.978)	54.34 (47.48)
Mean	15.49 (17.93)	21.38 (22.59)	25.65 (26.19)	28.57 (29.29)	22.77 (24.00)	14.43 (17.18)	20.19 (21.78)	24.72 (25.20)	26.71 (28.01)	21.51 (23.04)	

Figures in parentheses are angular transformed values

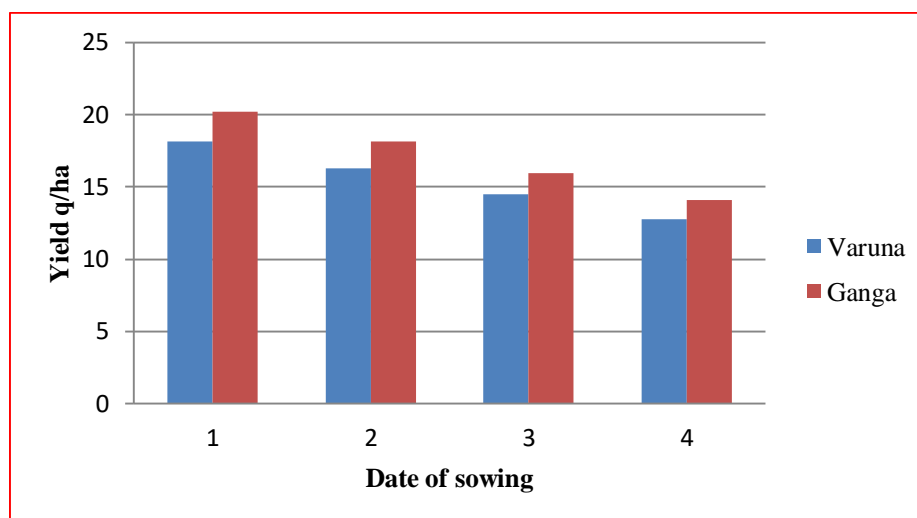
	<b>C.D.</b>	<b>SE<sub>(m)</sub></b>
Variety	0.41	0.07
Date of sowing	0.35	0.11
Variety × date of sowing	NS	0.17
Interval	0.67	0.24
Variety × interval	NS	0.34
Date of sowing × interval	1.33	0.48
Variety × date of sowing × interval	NS	0.68

Lowest mean PDI of the disease (15.49 and 14.43%) was recorded from the 1<sup>st</sup> sown plots on 20 October and the highest mean PDI of 28.57 and 26.71% was recorded from 4<sup>th</sup> sowing on 10<sup>th</sup> November in variety Varuna and Ganga, respectively and differed significantly (Table 11). Varuna variety experienced significantly greater mean disease severity (22.77%) as compared to Ganga variety (21.51%). Overall mean PDI of the disease increased with the time and reached maximum (54.34%) on 16 weeks after sowing and thereafter remained static.

**Table 12. Yield of mustard at different dates of sowing**

No. of sowing	Date of sowing	Seed yield (q/ha)		
		Varuna	Ganga	Mean
1st	20-10-2019	18.14	20.23	19.18
2nd	27-10-2019	16.28	18.16	17.22
3rd	03-11-2019	14.52	15.95	15.23
4th	10-11-2019	12.73	14.06	13.39
	Mean	15.41	17.10	

	<b>CD<sub>0.05</sub></b>	<b>SE<sub>(m)</sub></b>
Variety	1.54	0.23
Date of Sowing	1.64	0.52
Date of sowing × variety	N/S	0.47



**Figure 6. Yield of mustard at different dates of sowing**



(a)



(b)



(c)



(d)

**Plate 4. Effect of different dates of sowing on Alternaria blight of mustard (Varuna), a) 1<sup>st</sup> sowing, b) 2<sup>nd</sup> sowing, c) 3<sup>rd</sup> sowing and d) 4<sup>th</sup> sowing**

Data presented in Table 12 shows that the maximum mean yield of 19.18 q/ha was obtained from mustard crop sown on 1<sup>st</sup> date i.e. 20<sup>th</sup> October which significantly reduced with the delay in sowing and was minimum in 4<sup>th</sup> sowing (13.39 q/ha). Ganga variety resulted in more average yield (17.10 q/ha) as compared to Varuna (15.41 q/ha) which also differed significantly from each other (Fig. 6, Plate 4).

#### **4.6.2.1 Area under disease progress curve (AUDPC)**

AUDPC was obtained by plotting the area between curve and the X-axis to know the comparative effect of different sowing dates on progress of the disease (Fig. 7, 8). Minimum AUDPC of 1236.11 and 1146.28 was resulted in 1<sup>st</sup> sowing in varieties Varuna and Ganga, respectively. AUDPC increased with the delay in sowing with maximum AUDPC of 2007.72 and 1862.14 in 4<sup>th</sup> sowing of Varuna and Ganga, respectively showing increase in progress of disease with successive sowing of mustard crop. The AUDPC was lower in Ganga as compared to Varuna in all the sowings illustrating comparatively slow progress of Alternaria blight in Ganga as compared to Varuna.

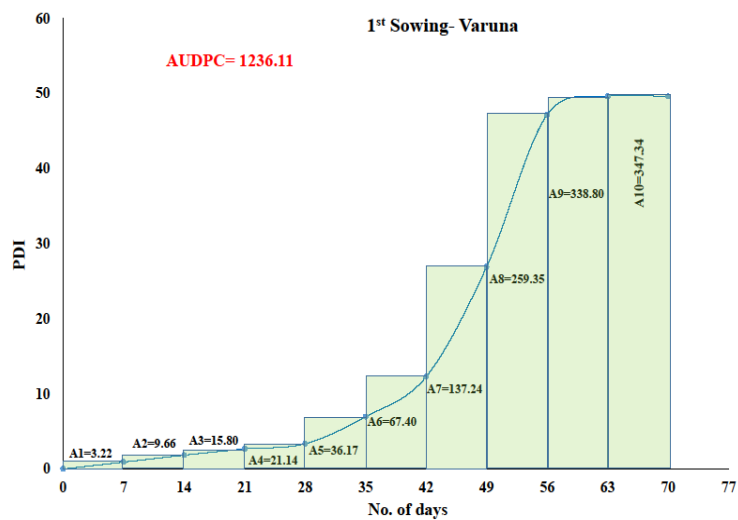
### **4.7 Management studies**

In the present studies, three systemic, three combi and three non-systemic fungicides were evaluated both under *in vitro* as well as *in vivo* conditions.

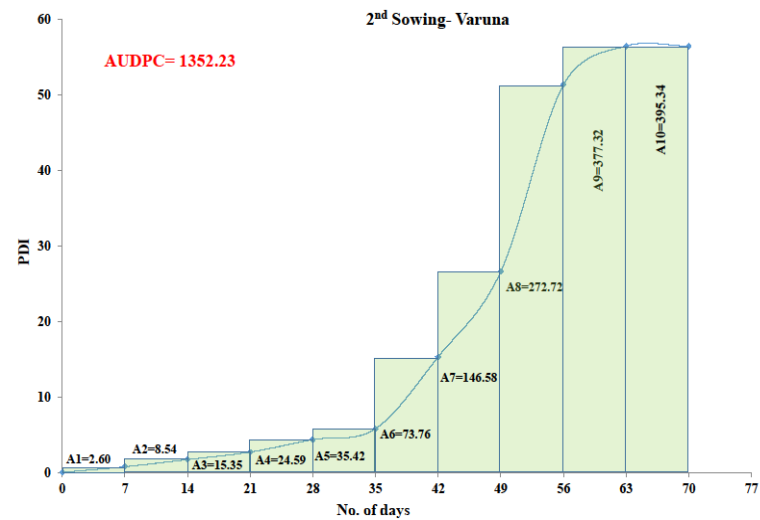
#### **4.7.1 *In vitro* evaluation of systemic and combi fungicides**

Efficacy of six different systemic and combination fungicides viz., propiconazole 25% EC (Vijeta), azoxystrobin 23% SC (Mirador), hexaconazole 5% EC (Contaf), captan 70% + hexaconazole 5% WP (Taqat), carbendazim 12% + mancozeb 63% WP (Crossman) and metalaxyl 8% + mancozeb 64% WP (Matco) were evaluated *in vitro* against *A. brassicae* at 100, 250, 500 and 1000 ppm using poisoned food technique (3.2.8.1).

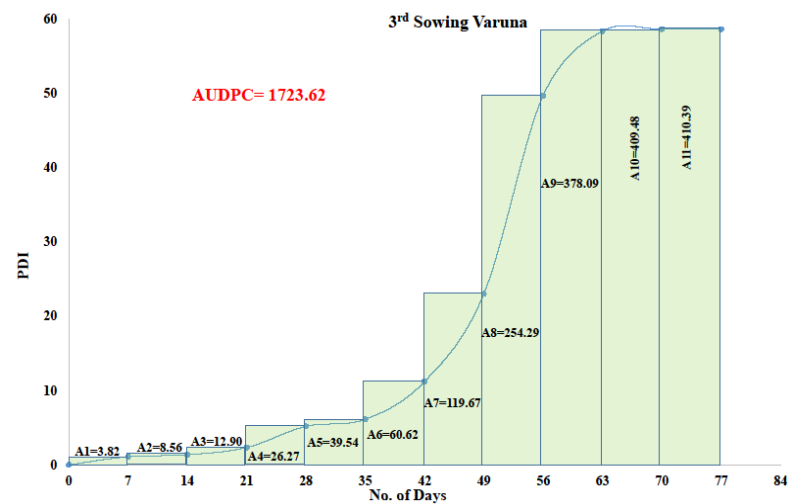
It is evident from the data presented in Table 13 that the fungicides significantly inhibited the growth of *A. brassicae* as compared to control.



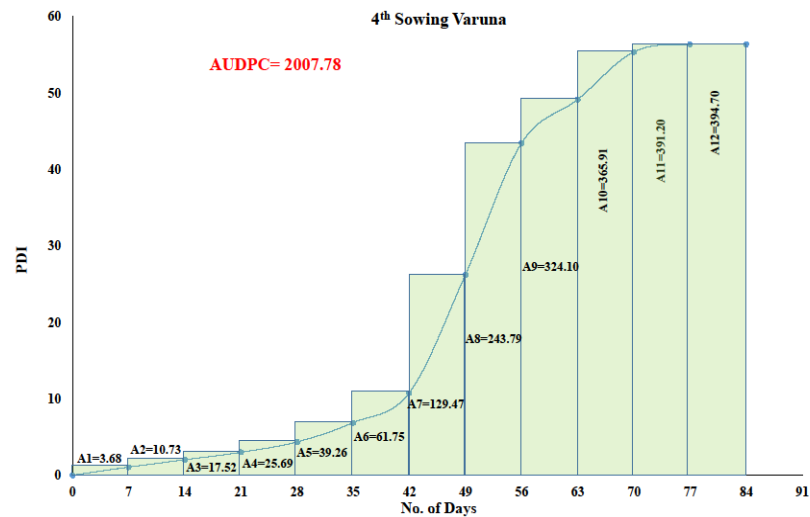
(a)



(b)

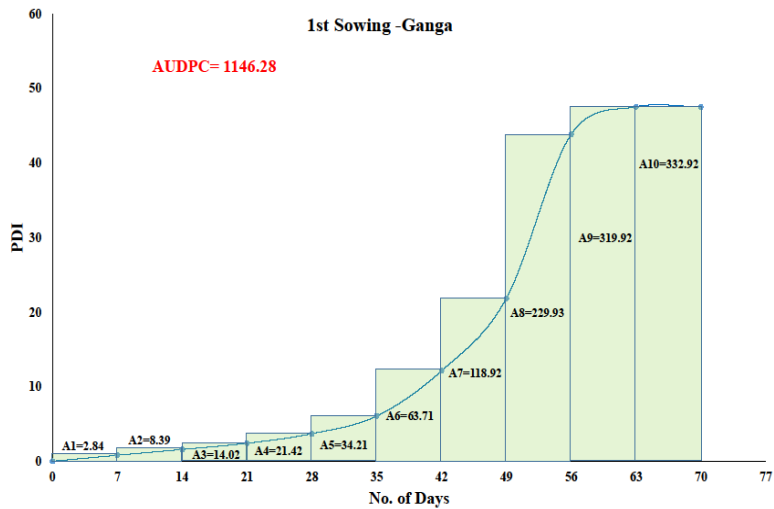


(c)

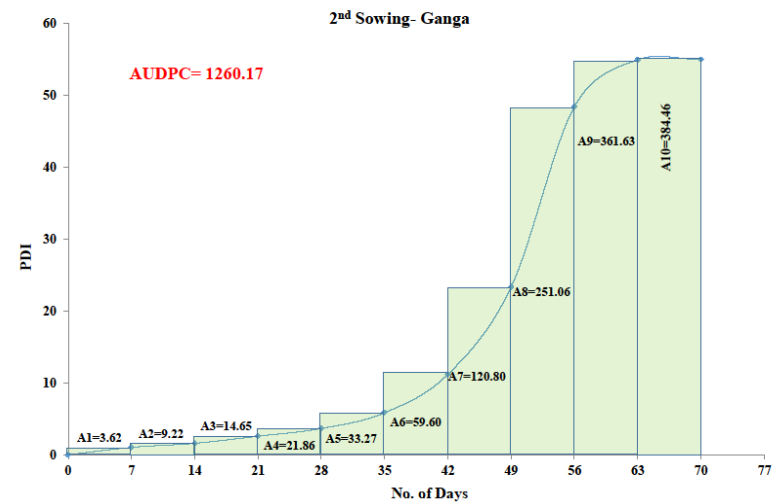


(d)

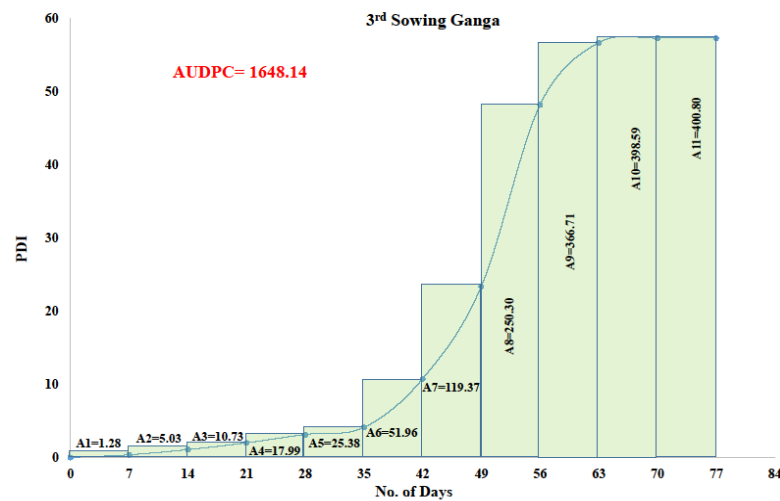
Figure 7. Area Under Disease Progress Curve on different date of sowing in Varuna, a) 1<sup>st</sup> b) 2<sup>nd</sup> c) 3<sup>rd</sup> and d) 4<sup>th</sup> sowing



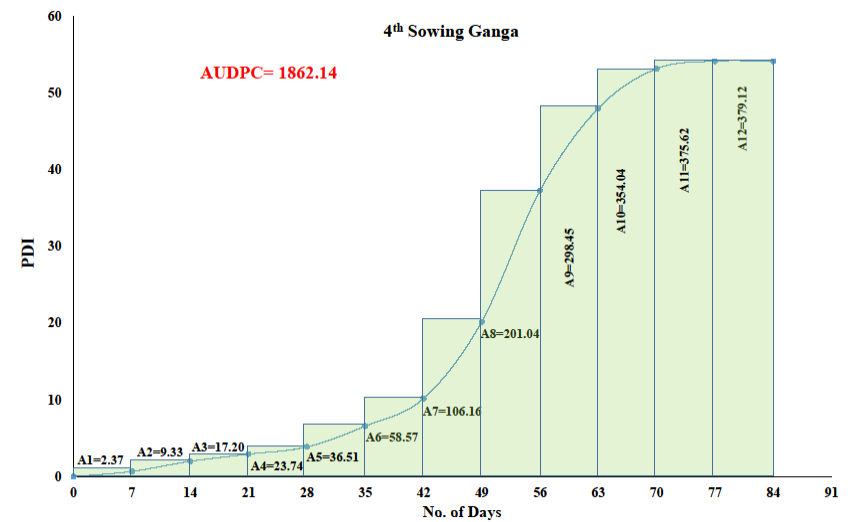
(a)



(b)



(c)



(d)

Figure 8. Area Under Disease Progress Curve on different date of sowing in Ganga, a) 1<sup>st</sup> b) 2<sup>nd</sup> c) 3<sup>rd</sup> and d) 4<sup>th</sup> sowing

Propiconazole, hexaconazole and captan + hexaconazole were the most effective and statistically at par among all the treatment against *A. brassicae* with no growth and cent per cent inhibition of test fungus in all the tested concentrations (Fig 9, 10). Next effective fungicides were metalaxyl + mancozeb resulting in 5.71mm mean mycelial growth and 93.66% average mycelial growth inhibition and carbendazim + mancozeb with 7.29 mm mean mycelial growth and 91.90% average mycelial growth inhibition in all the concentrations which also statistically differed from each other.

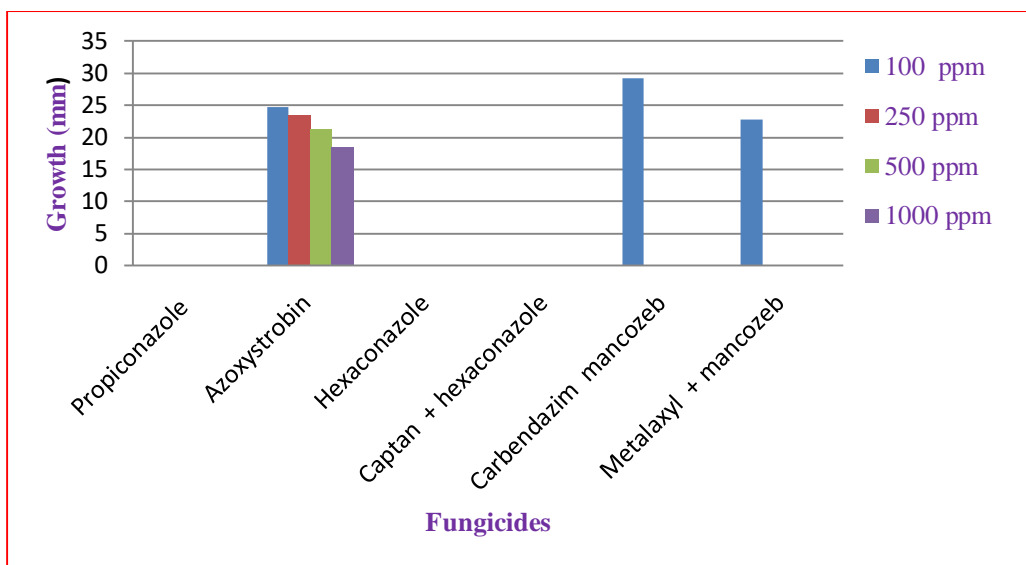
**Table 13. *In vitro* evaluation of systemic and combi fungicides against *A. brassicae***

S. no.	Fungicide	Growth of <i>A. brassicae</i> (mm) at concentrations				Mean	Growth inhibition (%) of <i>A. brassicae</i> at concentrations				Mean
		100 ppm	250 ppm	500 ppm	1000 ppm		100 ppm	250 ppm	500 ppm	1000 ppm	
1	Propiconazole 25% EC	0.00	0.00	0.00	0.00	0.00	100 (10.06)	100 (10.06)	100 (10.06)	100 (10.06)	100 (10.06)
2	Azoxystrobin 23% SC	24.66	23.50	21.34	18.50	22.0	72.60 (8.57)	73.89 (8.65)	76.47 (8.80)	79.45 (8.96)	75.60 (8.75)
3	Hexaconazole 5% EC	0.00	0.00	0.00	0.00	0.00	100 (10.06)	100 (10.06)	100 (10.06)	100 (10.06)	100 (10.06)
4	Captan 70% + hexaconazole 5% WP	0.00	0.00	0.00	0.00	0.00	100 (10.06)	100 (10.06)	100 (10.06)	100 (10.06)	100 (10.06)
5	Carbendazim 12% + mancozeb 63% WP	29.17	0.00	0.00	0.00	7.29	67.59 (8.29)	100 (10.06)	100 (10.06)	100 (10.06)	91.90 (9.60)
6	Metalaxyl 8% + mancozeb 64 % WP	22.83	0.00	0.00	0.00	5.70	74.62 (8.69)	100 (10.06)	100 (10.06)	100 (10.06)	93.66 (9.71)
7	Control	90.0	90.0	90.0	90.0	90.0					
	Mean	23.81	16.22	15.90	15.50		85.80 (9.29)	95.64 (9.81)	96.08 (9.84)	96.57 (9.87)	

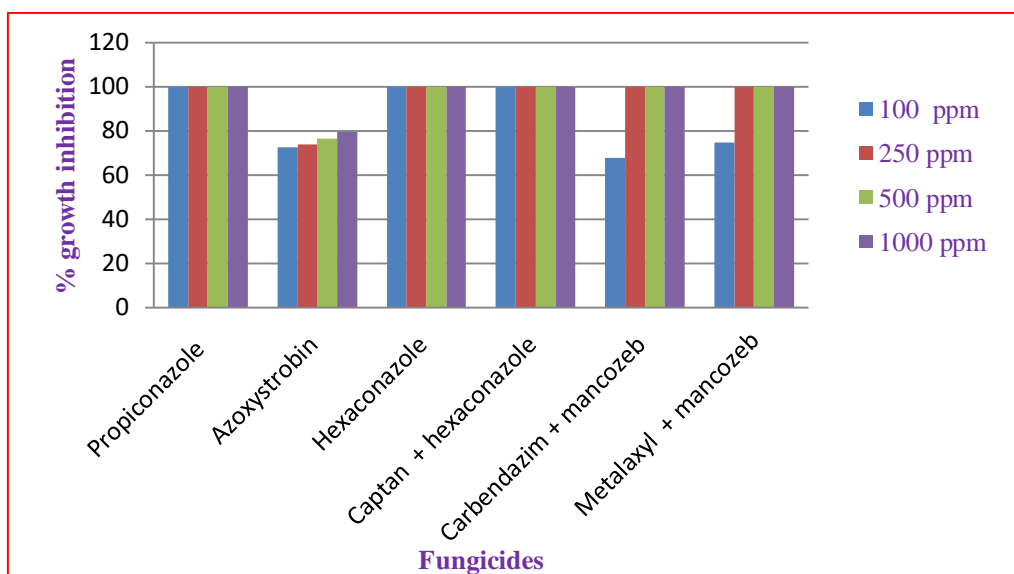
Figures in parentheses are square root transformed values

	CD <sub>0.05</sub>	SE <sub>(m)</sub>	CD <sub>0.05</sub>	SE <sub>(m)</sub>
Fungicide	0.49	0.24	0.04	0.02
Concentration	0.37	0.18	0.03	0.02
Interaction	0.98	0.49	0.08	0.03

Whereas, least effective fungicide was azoxystrobin which resulted in 22.0 mm mean mycelial growth and 75.60% mycelial growth inhibition of the test pathogen. It was noticed that with the increase in concentration of the fungicides the per cent mycelial growth of the fungus was also increased significantly.



**Figure 9.** Growth of *A. brassicae* under *in vitro* evaluation of systemic and combi fungicides



**Figure 10.** Growth inhibition of *A. brassicae* under *in vitro* evaluation of systemic and combi fungicides

#### 4.7.2 *In vitro* evaluation of non-systemic fungicides against *A. brassicae*

Efficacy of three non-systemic fungicides viz. mancozeb 75% WP (Indofil M-45), propineb 70% WP (Antracol) and wettable sulphur 90% DP (Diamond) were tested *in vitro* against the *A. brassicae* by poisoned food technique at 250, 500, 1000 and 2000 ppm (Plate 5, Fig. 11, 12).

**Table 14** *In vitro* evaluation of non-systemic fungicides against *A. brassicae*

S. no.	Fungicide	Growth of <i>A. brassicae</i> (mm) at concentrations				Mean	Growth inhibition (%) of <i>A. brassicae</i>				Mean
		250 ppm	500 ppm	1000 ppm	2000 ppm		250 ppm	500 ppm	1000 ppm	2000 ppm	
1	Propineb 70% WP	24.83	15.50	0	0	10.08	72.41 (8.55)	82.77 (9.16)	100 (10.06)	100 (10.06)	88.80 (9.46)
2	Mancozeb 75% WP	22.17	0	0	0	5.54	76.38 (8.79)	100 (10.06)	100 (10.06)	100 (10.05)	94.09 (9.73)
3	Wettable sulphur 80% WP	57.83	38.66	27.34	18.66	35.62	35.74 (6.06)	57.05 (7.61)	69.63 (8.41)	79.27 (8.95)	60.42 (7.75)
4	Control	90	90	90	90	90					
	Mean	48.70	36.05	29.34	27.17		61.50 (7.80)	79.93 (8.93)	89.87 (9.50)	93.09 (9.68)	

Figures in parentheses are square root transformed values

	CD <sub>0.05</sub>	SE <sub>(m)</sub>	CD <sub>0.05</sub>	SE <sub>(m)</sub>
Fungicide	1.95	0.67	0.15	0.08
Concentration	1.94	0.67	0.19	0.09
Interaction	3.89	1.35	0.32	0.16

Data presented in Table 14 clearly depicts that mancozeb was the most effective non-systemic fungicide in reducing the average mycelial growth of the test pathogen to 5.54 mm only with maximum per cent mycelial growth inhibition (94.09%) which was followed by propineb with 10.08 mm average mycelial growth only resulting in 88.80% average mycelial growth inhibition which statistically differed from the best treatment. Wettable sulphur was

the least effective non-systemic fungicide for growth inhibition of the fungus (60.42%). It was also noticed that as the concentration of fungicides increased, there was corresponding increase in per cent mycelial growth inhibition of *A. brassicae*.

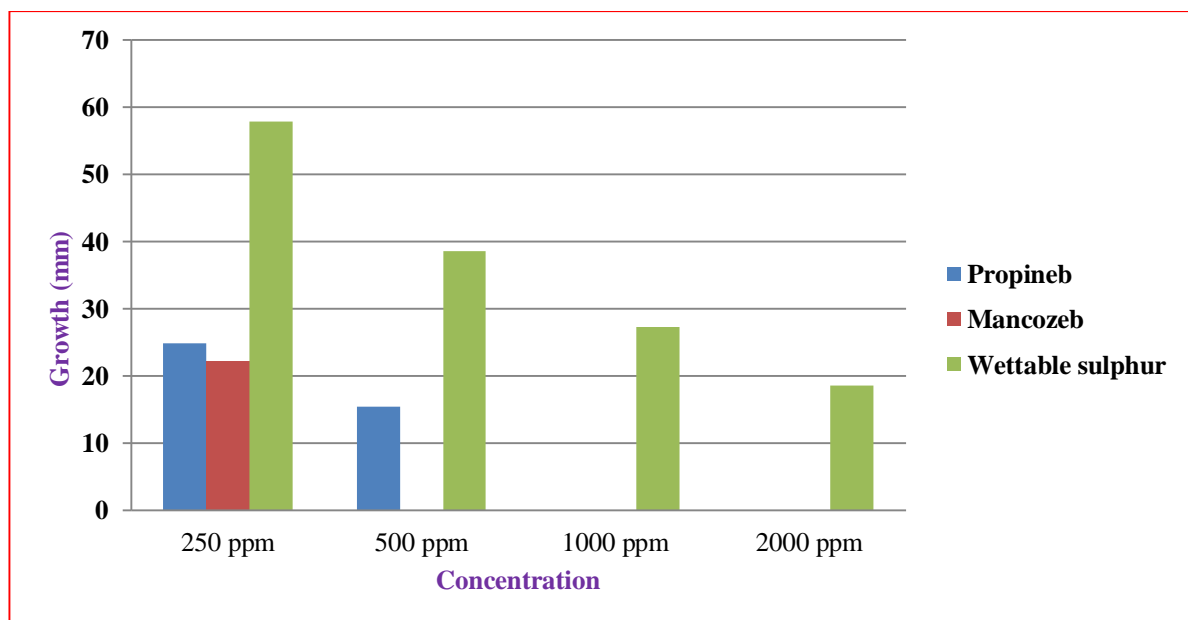


Figure 11. Growth of *A. brassicae* under *in vitro* evaluation of non-systemic fungicides

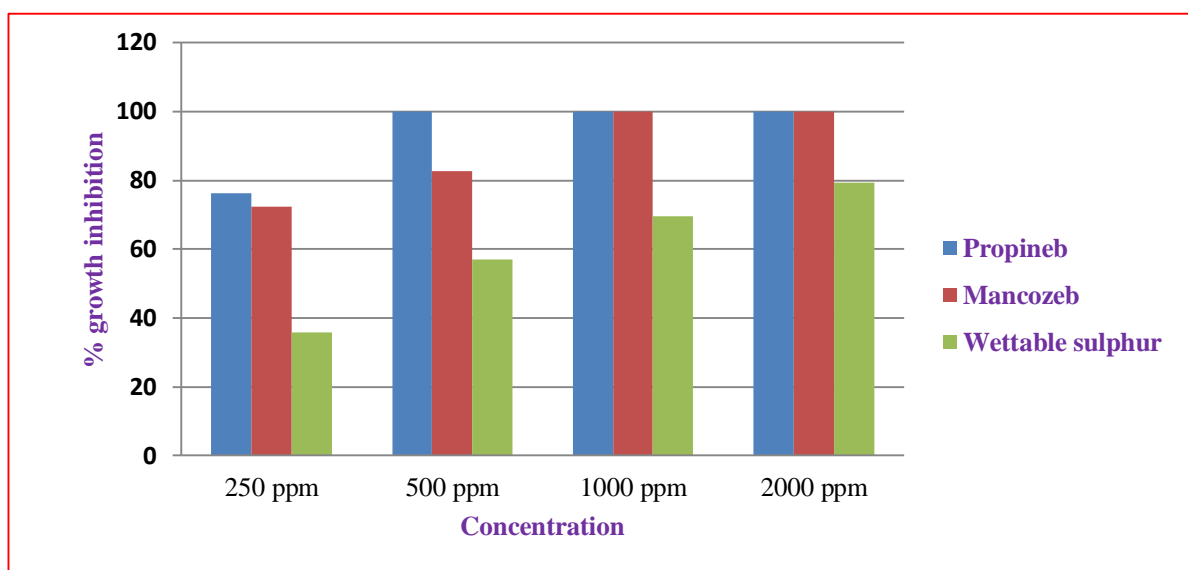
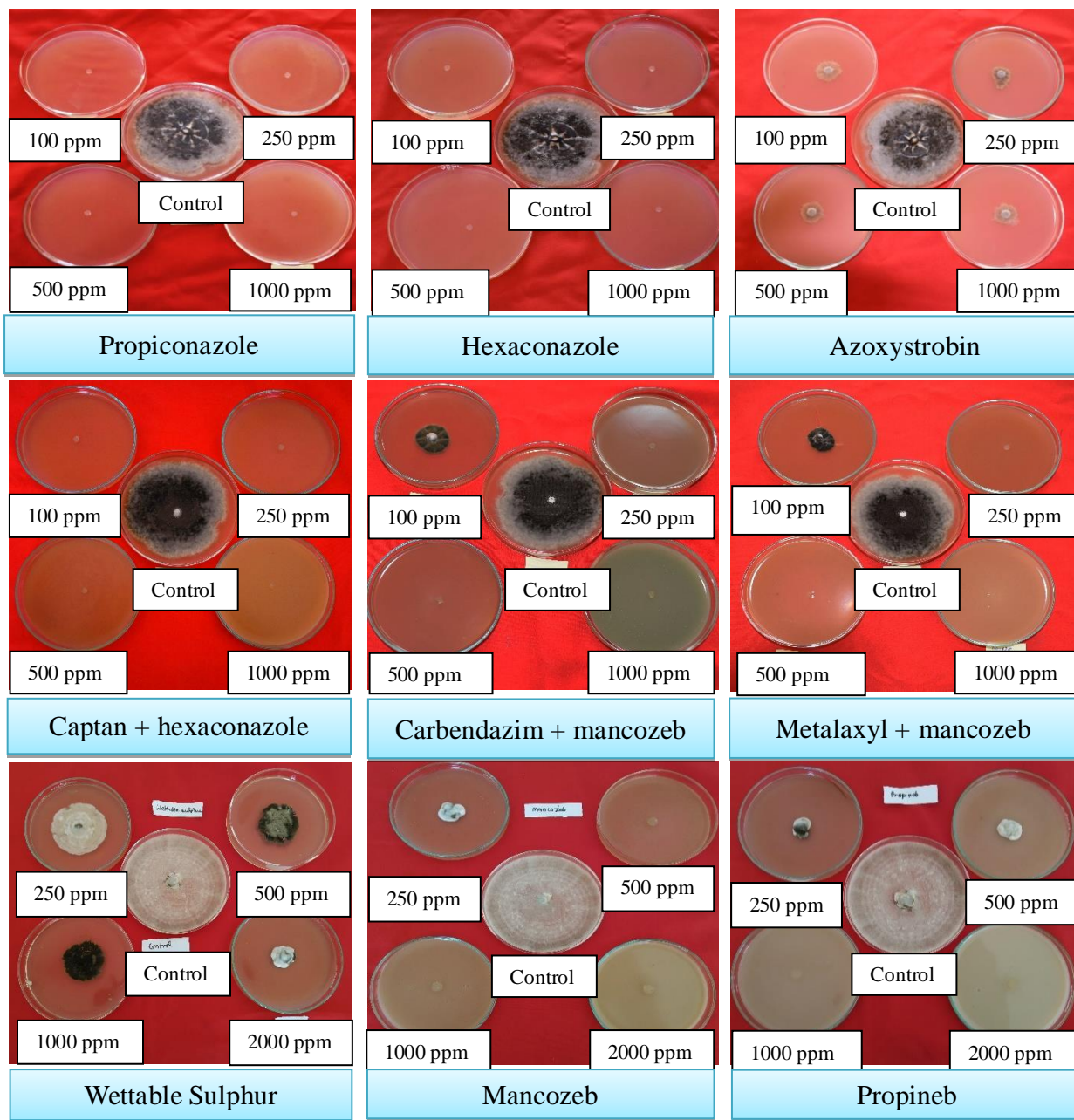


Figure 12. Growth inhibition of *A. brassicae* under *in vitro* evaluation of non-systemic fungicides



**Plate 5.** *In vitro* evaluation of fungicides against *A. brassicae*

#### 4.7.3 *In vivo* evaluation of fungicides against *Alternaria* blight of mustard

All nine fungicides evaluated for their bioefficacy against *A. brassicae* under *in vitro* were also evaluated under field conditions to know the most effective treatments in managing the *Alternaria* blight disease of mustard. Different fungicides sprayed were propiconazole 25% EC (Vijeta), azoxystrobin 23% SC (Mirador), hexaconazole 5% EC (Contaf) and captan 70% + hexaconazole 5% WP (Taqat) @ 0.1%; carbendazim 12% + mancozeb 63% WP (Crossman), metalaxyl 8% + mancozeb 64% WP (Matco) and propineb 70% WP (Antracol) @ 0.2%; mancozeb 75% WP (Indofil M-45) and wettable sulphur 90% DP (Diamond) @ 0.25% (Plate 6.)

**Table 15.** *In vivo* evaluation of fungicides against *Alternaria* blight of mustard

S. no.	Fungicide	Concentration (%)	Percent disease index (PDI)	Percent disease control (PDC)	Yield (q/ha)
1	Propiconazole 25 % SC	0.1	17.84 (24.96)	49.63	21.56
2	Azoxystrobin 23 % SC	0.1	22.24 (28.04)	37.23	18.32
3	Hexacoazole 5 % SC	0.1	20.21 (26.68)	42.97	19.82
4	Captan 70 % + hexaconazole 5 % EC	0.1	19.87 (26.39)	43.90	20.26
5	Carbendazim 12% + mancozeb 63% WP	0.2	25.29 (30.06)	28.62	18.43
6	Metalaxyl 8 % + mancozeb 64 % WP	0.2	22.07 (27.99)	37.69	17.23
7	Propineb 70 % WP	0.2	25.82 (30.47)	27.13	16.64
8	Mancozeb 75 % WP	0.25	25.33 (30.21)	28.51	15.49
9	Wettable sulphur 80 % WP	0.25	28.32 (32.14)	20.07	13.98
10	Control		35.43 (36.50)	-	12.96

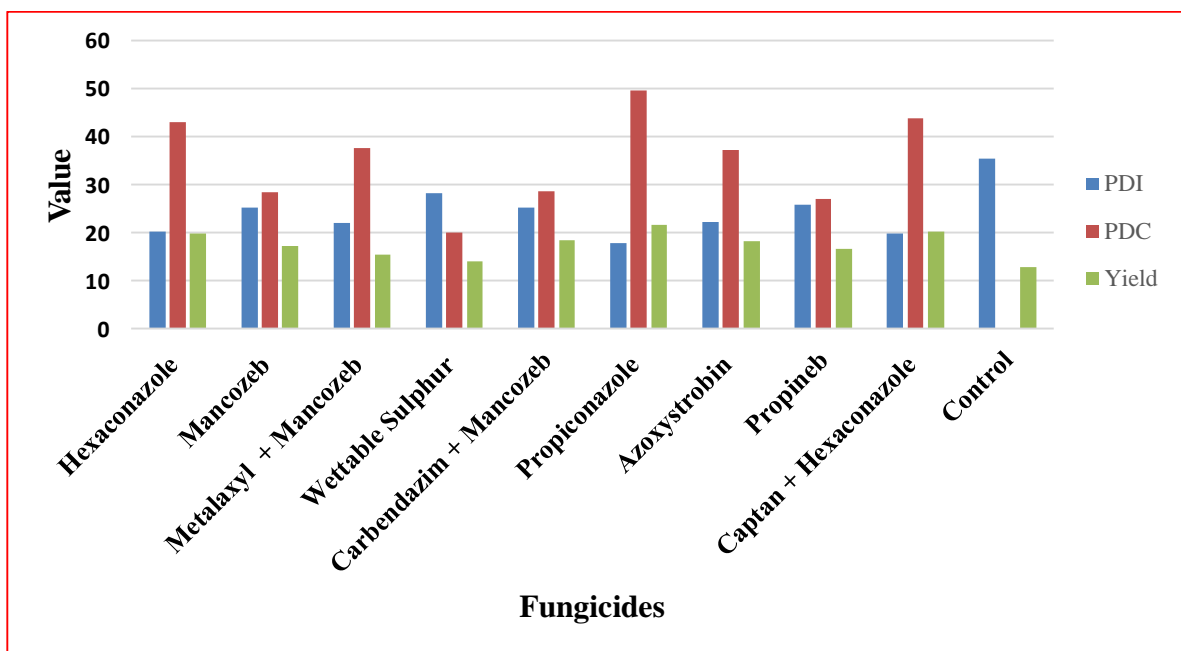
Figures in parentheses are angular transformed values

<b>CD<sub>0.05</sub></b>	3.16	1.38
<b>SE<sub>(m)</sub></b>	1.05	0.46
<b>CV</b>	6.24	4.57

It is evident from the data presented in Table 15 that all the treatments reduced the disease severity and also resulted in increase in the average yield of the crop as compared to control.

Propiconazole was most effective to reduce the disease severity of Alternaria blight to 17.84% followed by captan+ hexaconazole (19.87%) and hexaconazole (20.20%) and these fungicides did not differ significantly with each other. Whereas, wettable sulphur was least effective in reducing disease severity of Alternaria blight (28.31%).

All the fungicides were significantly superior as compare to control in increasing the seed yield. Best result was obtained with fungicide propiconazole (21.56 q/ha) followed by captan + hexaconazole (20.26 q/ha) and they did not differ from each other. It was followed by hexaconazole (19.82 q/ha). Wettable sulphur (13.98 q/ha) resulted in least yield of 13.98 q/ha followed by mancozeb (15.49 q/ha) and propineb (16.44 q/h) and both were statistically at par with each other (Fig. 13).



**Figure 13. PDI, PDC and Yield under *in vivo* evaluation of fungicides against Alternaria blight of mustard**



**a) *In vivo* evaluation of fungicides against Aternaria blight of mustard**



**b) Hexaconazole**



**c) Captan +  
hexaconazole**



**d) Propiconazole**



**e) Control**

**Plate 6. *In vivo* evaluation of fungicides against Alternaria blight**

### DISCUSSION

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Rapeseed-mustard belonging to the family Brassicaceae is one of the most important oilseed crops being grown in India and other countries. India is the third largest rapeseed-mustard growing country occupying an area of 6.23 million ha with production of 9.34 million tonnes while, Uttar Pradesh produces 1.12 million tonnes oilseeds from 0.753 million ha land sharing 11.96% of the total countries rapeseed-mustard oilseed production (Anonymous, 2019). Among the various diseases hampering the production of oilseed brassicas, Alternaria blight caused by *Alternaria brassicae* (Berk.) Sacc. is the most serious ones responsible for reduced quality and quantity of the mustard oilseed.

Alternaria blight of rapeseed-mustard has been reported widespread and destructive disease throughout the world. Alternaria genus was first described by Nees (1817) with the type species *A. tenuis* which was later renamed as *Alternaria alternata*. Berkeley (1836) was first to notice the fungal infection on plants belonging to the family Brassicaceae and identified the fungus as *Microsporium brassicae* (Berk.) which was later renamed as *Alternaria brassicae* (Berk.) Sacc. by Saccardo (1886). In India, Alternaria blight was first reported on sarsoan from Tirhoot in 1901 (Butler, 1918) but the fungus was thought to be new and described as *Sporodochium brassicae*. Later, Mason (1928) first observed the Alternaria species from a herbarium material of mustard from Pusa (Bihar). The disease has been resulting in heavy losses in seed yield and quality (Kotle, 1985) causing a yield loss of 10-71% in India (Chattopadhyay, 2008) and upto 30% in Canada (Conn *et al.*, 1990). The disease is greatly influenced by weather parameters and mostly higher disease incidence occurs in regions experiencing wet season and high relative humidity (Mehta, 2019). Keeping in view the importance and extent of the disease, detailed investigations were planned on epidemiological studies and management and results obtained are discussed here in the light of available literature.

Symptoms of the *Alternaria* blight appeared on lower leaves of the mustard plants (*Brassica juncea* L.) as black point sized necrotic spots, which later enlarged and developed into several sized round spots with concentric rings. Most of the spots were dark brownish with distinct grayish centres. After few days the disease also occurred on the middle and upper leaves. Small, black coloured and round shaped conspicuous spots appeared on the siliquae. Blister like symptoms were also seen on the siliquae. Various spots coalesce together leading to complete blackening and chlorosis resulting in defoliation of leaves and rotting of siliquae. Symptoms of *Alternaria* blight disease also appeared on the stem under severe conditions as purple to black coloured spots which weakened the affected stem of the plants. Chupp and Sherf (1960) reported spots produced by *A. brassicae* appear to be usually greyish coloured compared with black sooty velvety spots produced by *A. brassicola*. Similar characteristic symptoms of the disease observed on leaves, siliquae and stem has also been described by Kumar *et al.* (2014b).

*Alternaria brassicae* was isolated in pure culture from the affected leaves of mustard plant in potato dextrose agar and corn meal agar by hyphal tip method. Pathogen was purified through single spore technique and transferred in fresh slants containing CMA and PDA media. For the further studies of *A. brassicae* sub-culturing at the 30 days' intervals were done and the cultures were and maintained in the refrigerator at 4°C temperature. Similar media were also used by different workers for isolation and purification of *A. brassicae* (Sharma *et al.*, 2013; Pramila *et al.*, 2014; Singh *et al.*, 2017; Kumar and Singh, 2018).

Based on the different morphological and cultural characters, the identity of the pathogen was confirmed to be *Alternaria brassicae* as documented in standard authentic descriptions and taxonomic keys given by Simmons (2007). Mycelial growth on poured Petri plate were initially white then olivaceous green/ light black to brown coloured in PDA and depressed mycelial growth with olivaceous to light black coloured colonies in CMA media. Microscopic observations of the pathogen revealed mycelium as septate, branched, light brown to dark brown in colour. Most of the conidia of the pathogen were attached in 2-3 in chains. Conidia were borne singly from apex of conidiophores and were light to dark olivaceous to brown coloured, septate with 5-12 transverse and 0-4 longitudinal septa,

obclavate and muriform shaped with prominent long beak which was pale brown and nearly cylindrical shaped. These findings corroborate with observations made by Jolly (1964); Subramanian (1971); Kolte (1985); Singh (1998) and Singh *et al.* (2015).

Pathogenicity test of the pathogen was also proved in the present study by spraying the inoculum of *A. brassicae* @10<sup>4</sup> spores/ml on leaves of the healthy plants grown in pots. Symptoms developed on pot plants were same as recorded in the plant from which the pathogen was isolated. Pathogen was re-isolated from the infected pot plants and again examined under the microscope in which morphological characters like shape, size and colour of the conidia reported same as earlier cultured *Alternaria brassicae*. Similar technique and observations were reported by many workers who have worked on *Alternaria* blight of mustard (Yadav *et al.*, 2019; Rakesh, 2018).

In screening trial of oilseed brassicas conducted at agriculture farm of Banda University of Agriculture and Technology, Banda during two rabi seasons 2018-19 and 2019-20 in which a total of 35 germplasm of SBG-18 and 61 germplasm of UDN-18 were screened. Out of the 32 germplasm of SBG-18, no germplasm was found to be immune or highly resistant, one germplasm was found as resistant (SBG-18- 29), five germplasm were moderate resistant SBG-18-4, 12, 13, 14 and 15, one germplasm was moderate susceptible (SBG-18-31), 17 germplasm were susceptible and 8 germplasm were highly susceptible. Out of 60 germinated genotypes of the UDN-18 series none was found as immune or highly resistant, whereas, two germplasm were found as resistant (UDN-18-44, 51), two germplasm were moderately resistant (UDN-18-2 and 8), 8 germplasm were moderately susceptible 47 germplasm were found as susceptible and 1 germplasm was found as highly susceptible (UDN-18-35). Different germplasm of oilseed brassicas has been screened by various workers in the past for any source of resistance against *Alternaria* blight (Kumar, 2008; Singh *et al.*, 2009; Rahman *et al.*, 2010; Yadav *et al.*, 2014; Talukdar and Das, 2015; Singh *et al.*, 2018a; Summuna *et al.*, 2018 and Kumar *et al.*, 2019). Singh *et al.* (2018b) also found none of the entry as resistant whereas, twenty two genotypes were reported moderately resistant and 63 genotypes were reported as moderately susceptible. SBG-18 and UDN-18 germplasm were

also screened at various AICRP- Rapeseed-mustard centres in which none of the germplasm was reported as immune or highly resistant (AICRP, 2019).

Different weather parameters greatly influence the *Alternaria* blight of mustard and higher disease incidence mostly occurs in regions experiencing wet season and high relative humidity (Mehta, 2019). Therefore, in the present investigations effect of different weather parameters viz., average maximum and minimum temperature ( $^{\circ}\text{C}$ ), average morning, noon and evening relative humidity (%) and average rainfall (mm) on per cent disease index of *Alternaria* blight on Varuna and Ganga varieties of Indian mustard sown on 20<sup>th</sup> October 2019 was studied. First symptom of *Alternaria* blight in Varuna and Ganga appeared on 49<sup>th</sup> meteorological week i.e. eight weeks after sowing during which the maximum average temperature recorded was  $22.14^{\circ}\text{C}$ , minimum average temperature was  $10.29^{\circ}\text{C}$ , average morning RH was 91.57%, average noon RH was 60.57%, average evening RH was 80.57% and total weekly rainfall of 19.2 mm was received. Favourable temperature, rainfall of 19.2 mm in 8<sup>th</sup> week and >90% average weekly morning RH definitely had prolonged the leaf wetness hours which might have provided the congenial environmental conditions for infection of *Alternaria brassicae* on mustard leaves. After 8<sup>th</sup> sowing week disease severity increased gradually and risen exponentially in 13<sup>th</sup> week after sowing in which 19.1mm rainfall was received. The highest disease severity was observed in 16<sup>th</sup> week in which average weekly maximum temperature was  $23.57^{\circ}\text{C}$  with >80 % average morning RH. Shrestha *et al.* (2005) also observed increase in number of spots in February from only few spots in lower leaves during third week of January when maximum temperature ranged  $15-20^{\circ}\text{C}$ , minimum temperature ranged  $1-5^{\circ}\text{C}$  and relative humidity was more than 80%. Sangeetha and Siddaramaiah (2007) also found maximum temperature ranging  $26-29^{\circ}\text{C}$ , minimum temperature of  $14-15^{\circ}\text{C}$  and average relative humidity >65% favoured the development of *Alternaria* blight in mustard. Jha *et al.* (2013) also observed that maximum temperature of  $23.2^{\circ}\text{C}$  and maximum and minimum relative humidity (RH) of >80% and 66%, respectively favoured the development of *Alternaria* blight in mustard. Mehta (2019) observed the development of *Alternaria* blight to favour by the maximum temperature of  $20-25^{\circ}\text{C}$ , minimum temperature of  $15^{\circ}\text{C}$ , relative humidity in morning >90% and relative humidity in evening >50%.

In the present study, per cent disease index of *Alternaria* blight of mustard was reported positively correlated with the average minimum temperature whereas, it was significantly negative correlated with the average evening relative humidity in both the varieties. PDI of *Alternaria* blight was recorded negatively correlated with all other weather parameters in both the varieties. Multiple regression analysis of the PDI of *Alternaria* blight with different weather parameters revealed that regression coefficient was significant at 5% level with Maximum Temp. and RH Noon whereas, it was significant with Minimum Temp. and RH Evening at 1% level for both Varuna and Ganga. Coefficient of Determination ( $R^2$ ) of 0.812 was calculated in Varuna which implies that all the weather parameters were 81.2 per cent associated for PDI of *Alternaria* blight. Coefficient of Determination ( $R^2$ ) of 0.818 was calculated in Ganga which implies that all the weather parameters were 81.8 per cent associated for PDI of *Alternaria* blight. Gupta *et al.* (2003) also reported highest disease severity of *Alternaria* blight in eighty five days old mustard plants at maximum temperature (20.4-31.6°C) and minimum temperature (4.9-14.4°C) and both were significantly negatively correlated with disease severity. Jain and Sandhu (2019) also observed that the maximum temperature, minimum temperature and sunshine hours showed a significant positive correlation with disease severity while morning relative humidity had a significant negative correlation with disease severity. Dhaliwal and Singh (2020) reported that the maximum temperature ranged 15.7–30.3°C and minimum temperature ranging 3.3–12.6°C had positive correlation with disease severity. Similar findings have been reported by Awasthi and Kolte (1994); Mahapatra and Das (2014).

Effect of different dates of sowing on PDI of the *Alternaria* blight at weakly intervals starting from first appearance of symptom and average yield (q/ha) of Varuna and Ganga varieties of Indian mustard at harvest in all the four sowing dates was evaluated in the current study in which lowest mean PDI of the disease (15.49 and 14.43%) was recorded from the 1<sup>st</sup> sown plots on 20<sup>th</sup> October and the highest mean PDI of 28.57 and 26.71% was recorded from 4<sup>th</sup> sowing on 10<sup>th</sup> November in variety Varuna and Ganga, respectively and differed significantly. Jain and Sandhu (2019) also reported that mustard cultivars (RLC-3 and PBR-357) sown on different dates viz. 10<sup>th</sup> October, 5<sup>th</sup> November and 1<sup>st</sup> December that late sown

crop showed higher disease severity of 44.2 & 51.5% followed by the normal (39.7 & 45.5%) and early sown crop (31.5 & 40.0%), respectively for RLC-3 and PBR-357. Dhaliwal and Singh (2020) also reported a significant difference among the sowing dates and varieties of mustard. RLC-3 showed maximum PDI (52.19%) whereas, minimum PDI (0.98%) was reported in PC-6. Maximum seed yield (20.37q/ha) was recorded in 1<sup>st</sup> sowing followed by 2<sup>nd</sup> sowing (12.59 q/ha). Low disease severity of Alternaria blight of mustard in early sown crop as compared to late sown crop has also been reported by several other workers (Bali *et al.*, 1992; Patel *et al.*, 1994; Rashid *et al.*, 1995; Gupta *et al.*, 2003; Khatun *et al.*, 2011). In present study maximum mean yield of 19.18 q/ha was obtained from mustard crop sown on 1<sup>st</sup> date i.e. 20<sup>th</sup> October which significantly reduced with the delay in sowing and was minimum in 4<sup>th</sup> sowing (13.39 q/ha). Ganga variety resulted in more average yield (17.10 q/ha) as compared to Varuna (15.41 q/ha) which also differed significantly from each other. These results are in accordance with the Alam *et al.* (2014) who reported from their studies that first sowing date (25<sup>th</sup> October) produced a good yield than the later dates of sowing of mustard. Gawariya *et al.* (2015) also observed that crop sown on 1<sup>st</sup> October gave significantly higher yield attributing characters viz. number and weight of silique/plant, dry matter accumulation and seed yield (2013 Kg/ha) as compared to the crop sown on 31<sup>st</sup> October and 15<sup>th</sup> November. Similar results were also reported by Rahman and Shahjahan (1986); Howlider *et al.* (1989). During current study the area under disease progress curve (AUDPC) was also plotted in which minimum AUDPC of 1236.11 and 1146.28 was resulted in 1<sup>st</sup> sowing in varieties Varuna and Ganga, respectively. AUDPC increased with the delay in sowing with maximum AUDPC of 2007.72 and 1862.14 in 4<sup>th</sup> sowing of Varuna and Ganga, respectively showing increase in progress of disease with successive sowing of mustard crop. Jain and Sandhu (2019) also recorded that AUDPC of Alternaria blight was highest in late sowing (162) followed by normal (148) and early (126) sowing in mustard cultivars RLC-3 and PBR-357. Dhaliwal and Singh (2020) also observed highest AUDPC in RLC-3 variety (3885.91) of mustard with 3<sup>rd</sup> sowing and the lowest AUDPC was recorded in PC-6 (54.77) with 1<sup>st</sup> sowing.

Various methods have been evaluated for the management of Alternaria blight of mustard throughout the world and among them judicious use of fungicides still is one of the most effective management measures. In the present studies, three systemic, three combi-

fungicides and three non-systemic fungicides were evaluated under *in vitro* conditions through poisoned food technique for their inhibitory effect on *Alternaria brassicae* causing Alternaria blight of mustard. Among six different systemic and combination fungicides evaluated at 100, 250, 500 and 1000 ppm concentrations propiconazole, hexaconazole and captan + hexaconazole were the most effective and statistically at par among all the treatment against *A. brassicae* with no growth and cent per cent inhibition of test fungus in all the tested concentrations. Next effective fungicides were metalaxyl + mancozeb and carbendazim + mancozeb resulting in 93.66 and 91.90 per cent average mycelial growth inhibition, respectively. Whereas, among three non-systemic fungicides tested at 250, 500, 1000, and 2000 ppm concentrations, mancozeb was the most effective fungicide with 94.09 per cent average mycelial growth inhibition. All nine fungicides evaluated for their bio-efficacy against *A. brassicae* under *in vitro* were also evaluated under field conditions in which propiconazole was most effective to reduce the disease severity of Alternaria blight to 17.84% followed by captan+ hexaconazole (19.87%) and hexaconazole (20.20%) and these fungicides did not differ significantly with each other. Maximum yield was also obtained with fungicide propiconazole (21.56 q/ha) followed by captan + hexaconazole (20.26 q/ha) and hexaconazole (19.82 q/ha). Singh *et al.* (2013) evaluated different fungicides and reported propiconazole 25 EC @ 0.1% in maximum test weight and yield (6.057 g and 1366.66 Kg/ha) of mustard. Singh *et al.* (2018a) evaluated six fungicides in thirteen treatment combinations against Alternaria blight of Indian mustard in which propiconazole 25 EC @ 0.1% resulted as most effective treatment with minimum PDI (18.97% and 20.70%) followed by propiconazole 25 EC @ 0.05% (22.0% and 24.73%) and hexaconazole 5 SC @ 0.1% with 23.30% and 25.27% in year 2013-14 and 2014-15, respectively. Propiconazole 25 EC @ 0.1% also resulted in avoiding highest test weight loss (34.92%) and highest yield loss (48.67%) followed by same fungicide @ 0.05%. Efficacy of triazoles and their combination fungicides in reducing the Alternaria blight and increasing the yield has also been reported by several workers (Petraitiene and Brazauskiene, 2007; Mondal *et al.*, 2007; Bal *et al.*, 2014; Mahapatra and Das, 2016; Singh *et al.*, 2018b; Shiwangi *et al.*, 2019).

## **SUMMARY AND CONCLUSION**

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The present investigations on Alternaria blight of mustard caused by *Alternaria brassicae* (Berk.) Sacc. were undertaken with regard to screening of germplasm of oilseed brassicas, effect of weather parameters and date of sowing on Alternaria blight of *Brassica juncea* (L.) and disease management through chemicals.

The results obtained are summarized as under:

Symptoms of the Alternaria blight of mustard appeared on lower leaves of the plant as black point sized necrotic spots, which later enlarged and developed into several sized round spots with concentric rings. Most of the spots were dark brownish with distinct grayish centres. Small, black coloured and round shaped conspicuous spots appeared on the siliquae. Blister like symptoms were also seen on the siliquae. On stem, purple to black coloured spots were also noticed. The pathogen associated with the disease was isolated, pure cultured and identified as *Alternaria brassicae* (Berk.) Sacc. on the basis of different morphological and cultural characters.

Pathogenicity test of the pathogen was also proved by spraying the inoculum of *A. brassicae* @  $10^4$  spores/ml on the leaves of the healthy plants grown in pots and Koch's postulates were proved by isolating and confirming the same pathogen from artificially inoculated leaves.

In screening of oilseed brassicas varieties/lines, no germplasm was found to be immune or highly resistant, one germplasm was found as resistant (SBG-18- 29), five germplasm were moderate resistant SBG-18-4, 12, 13, 14 and 15, one germplasm was moderate susceptible (SBG-18-31), 17 germplasm were susceptible and 8 germplasm were highly susceptible out of the 32 germplasm of SBG-18. Out of 60 germinated germplasm of the UDN-18 series none was found as immune or highly resistant, whereas, two germplasm were found as resistant (UDN-18-44, 51), two germplasm were moderately resistant (UDN-

18-2 and 8), 8 germplasm were moderately susceptible 47 germplasm were found as susceptible and 1 germplasm was found as highly susceptible (UDN-18-35).

In epidemiological studies to found the effect of weather parameters on Alternaria blight of mustard the first symptom of the disease in Varuna and Ganga varieties of Indian mustard appeared on 49<sup>th</sup> meteorological week i.e. eight weeks after sowing during which the maximum average temperature recorded was 22.14°C, minimum average temperature was 10.29°C, average morning RH was 91.57%, average noon RH was 60.57%, average evening RH was 80.57% and total weekly rainfall of 19.2 mm was received.

Per cent disease index of Alternaria blight of mustard was reported positively correlated with the average minimum temperature whereas, it was significantly negative correlated with the average evening relative humidity in both the varieties. PDI of Alternaria blight was recorded negatively correlated with all other weather parameters in both the varieties. Regression coefficient was significant at 5% level with Maximum Temp. and RH Noon whereas, it was significant with Minimum Temp. and RH Evening at 1% level for both Varuna and Ganga. Coefficient of Determination ( $R^2$ ) of 0.812 and 0.818 was calculated in Varuna and Ganga, respectively.

Effect of different dates of sowing on PDI of the Alternaria blight at weakly intervals starting from first appearance of symptom and average yield (q/ha) of Varuna and Ganga varieties of Indian mustard at harvest in all the four sowing dates were also evaluated in which lowest mean PDI of the disease (15.49 and 14.43%) was recorded from the 1<sup>st</sup> sown plots on 20<sup>th</sup> October 2019 and the highest mean PDI of 28.57 and 26.71% was recorded from 4<sup>th</sup> sowing on 10<sup>th</sup> November 2019 in variety Varuna and Ganga, respectively and both differed significantly from each other.

Maximum mean yield of 19.18 q/ha was obtained from mustard crop sown on 1<sup>st</sup> date i.e. 20<sup>th</sup> October which significantly reduced with the delay in sowing and was minimum in 4<sup>th</sup> sowing (13.39 q/ha). Ganga variety resulted in more average yield (17.10 q/ha) as compared to Varuna (15.41 q/ha) which also differed significantly from each other. Minimum AUDPC of 1236.11 and 1146.28 was resulted in 1<sup>st</sup> sowing in varieties Varuna and Ganga, respectively.

Whereas, maximum AUDPC of 2007.72 and 1862.14 was resulted in 4<sup>th</sup> sowing of Varuna and Ganga, respectively.

Among six different systemic and combination fungicides evaluated *in vitro* against *A. brassicae*, propiconazole, hexaconazole and captan + hexaconazole were the most effective and statistically at par among all the treatment with no mycelium growth and 100 per cent mycelial growth inhibition in all the tested concentrations. Whereas, among three non-systemic fungicides, mancozeb was the most effective with 94.09 per cent average mycelial growth inhibition.

During *in vivo* evaluation of nine fungicides, propiconazole resulted as most effective to reduce the disease severity of Alternaria blight to 17.84% followed by captan + hexaconazole (19.87%) and hexaconazole (20.20%) and these fungicides did not differ significantly with each other. Maximum yield of Varuna and Ganga seeds were also obtained with propiconazole (21.56 q/ha) followed by captan + hexaconazole (20.26 q/ha) and hexaconazole (19.82 q/ha).

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## APPENDIX

**Anova: 1. Screening of oilseed brassicas germplasm (SBG-18-1 to 35) (Table 4)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Replication	1	2.92			
Germplasm	31	10,575.25	341.14	76.85	0
Replication	1	345.61	345.61	77.86	0
Germplasm X Replication	31	267.95	8.64	1.95	0.013
Error	63	279.65	4.44		
Total	127	11,471.38			

**Anova: 2. Screening of oilseed brassicas germplasm (UDN-18-1 to 61) (Table 5)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Replication	1	0.34			
Germplasm	59	7,525.08	127.544	47.65	0
Replication	1	1,013.76	1,013.76	378.71	0
Germplasm X Replication	59	529.75	8.98	3.35	0
Error	119	318.55	2.68		
Total	239	9,387.47			

**Anova: 3. Correlation coefficient between PDI of Alternaria blight and weather parameters (Table 9)**

Source of Variation	DF	Sum of Squares	Mean Sum of Square	F-Calculated	Sign. (P)
Regression	6	4,636.07	772.68	7.18	0.004
Residual	10	1,075.22	107.52		
Total	16	5,711.29			

**Anova: 4 Regression coefficient of PDI of Alternaria blight and weather parameters (Table 10)**

Source of Variation	DF	Sum of Squares	Mean Sum of Square	F-Calculated	Sign. (P)
Regression	6	4,140.15	690.03	7.487	0.003
Residual	10	921.58	92.16		
Total	16	5,061.73			

**Anova: 5. Per cent disease index of Alternaria blight on mustard leaves at different dates of sowing (Table 11)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Replication	2	9.26			
Variety	1	71.57	71.57	104.66	0.0094
Error(Variety)	2	1.37	0.68		
Date of sowing	3	5,338.39	1,779.47	1,750.59	0.0000
Variety X Date of sowing	3	3.30	1.10	1.08	0.3935
Error (Date of sowing)	12	12.19	1.02		
Weeks after Sowing	12	95,293.58	7,941.13	5,787.23	0.0000
Variety X Interval	12	21.28	1.77	1.29	0.2256
Date of sowing X Interval	36	3,404.52	94.57	68.92	0.0000
Variety X Date of sowing X Interval	36	68.66	1.91	1.39	0.0830
Error (Interval)	192	263.46	1.37		
Total	311	104,487.60			

**Anova: 6. Yield of mustard at different dates of sowing (Table 12)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Replication	2	1.06			
Variety	1	16.99	16.99	25.59	0.03691
Error(Variety)	2	1.32	0.66		
Date of sowing	3	200.53	66.84	39.95	0.00000
Variety X Date of sowing	3	0.59	0.19	0.12	0.94811
Error(Date of sowing)	12	20.08	1.67		
Total	23	240.57			

**Anova: 7. *In vitro* evaluation of systemic and combi fungicides against *A. brassicae* (Mycelial growth in mm) (Table 13)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Treatment	6	77,251.33	12,875.22	35,752.68	0.00000
Replication	3	997.45	332.48	923.26	0.00000
Treatment X Replication	18	2,155.84	119.77	332.58	-0.00000
Error	56	20.17	0.36		
Total	83	80,424.79			

**Anova: 8. *In vitro* evaluation of systemic and combi fungicides against *A. brassicae* (Mycelial growth inhibition %) (Table 13)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Treatment	5	15.33	3.06	1,699.91	0.00000
Replication	3	4.24	1.41	782.87	0.00000
Treatment X Replication	15	7.19	0.48	265.62	0.00000
Error	48	0.09	0.002		
Total	71	26.84			

**Anova: 9. *In vitro* evaluation of non-systemic fungicides against *A. brassicae* (Mycelial growth in mm) (Table 14)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Treatment	3	54,163.60	18,054.54	3,329.94	0.00000
Replication	3	3,385.02	1,128.34	208.11	0.00000
Treatment X Replication	9	1,647.69	183.08	33.77	0.00000
Error	32	173.50	5.42		
Total	47	59,369.82			

**Anova: 10. *In vitro* evaluation of non-systemic fungicides against *A. brassicae* (Mycelial growth inhibition %) (Table 14)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Treatment	2	27.45	13.73	397.41	0.00000
Replication	3	19.38	6.46	187.04	0.00000
Treatment X Replication	6	3.26	0.54	15.74	0.00000
Error	24	0.83	0.04		
Total	35	50.92			

**Anova: 11. *In vivo* evaluation of fungicides against *Alternaria* blight of mustard (Yield) (Table 15)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Replication	2	2.66			
Treatment	9	206.57	22.95	35.94	0.00000
Error	18	11.49	0.64		
Total	29	220.73			

**Anova: 12. *In vivo* evaluation of fungicides against *Alternaria* blight of mustard (PDI) (Table 15)**

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F-Calculated	Sign. (P)
Replication	2	48.11			
Treatment	9	300.10	33.35	9.93	0.00002
Error	18	60.43	3.36		
Total	29	408.64			

## **BIO-DATA**

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**Name** : Pradip Kumar  
**Father's Name** : Vardani  
**Mothers Name** : Foola Devi  
**Date of birth** : 18<sup>th</sup> April, 1996  
**Sex** : Male  
**Nationality** : Indian  
**Address** : Village- Kauhari, Post- Gyodi, District- Mahoba, (U.P.)  
**Contact No.** : 9935428564 & 8218425811  
**Email id** : [pradipkumar2794@gmail.com](mailto:pradipkumar2794@gmail.com)



### **Educational Qualifications :**

<b>Qualification</b>	<b>Name of the University/ Board</b>	<b>Year of completion</b>	<b>Subject(s)</b>	<b>Marks obtained (%)</b>	<b>Division</b>
10th /High School	P.N.V Inter College, Chilli Muskara, Hamirpur, (UP)	2011	Agriculture	66.84	1 <sup>st</sup>
10+2/ Intermediate	P.N.V Inter College, Chilli Muskara, Hamirpur, (UP)	2013	Agriculture	79.1	1 <sup>st</sup>
Graduation	S.V.P.U.&T. Modipuram, Meerut, (UP)	2018	Agriculture	71.38	1 <sup>st</sup>
Masters	Banda University of Agriculture and Technology, Banda (UP)	2020	Plant Pathology	77.77	1 <sup>st</sup>

**Place:** BUAT, Banda

**Date:** 25.11.2020

**Pradip Kumar**