

1 **ACCEPTED ARTICLE**

2 **Antifungal activity and role of *Terminalia* extracts in imparting resistance**  
3 **in barley against spot blotch by modulating metabolic defense mechanisms**

4  
5 Nitika Khattar<sup>1</sup>, Rajni Sharma<sup>1</sup>, Amrinder Kaur<sup>2</sup> and Rohit Chhabra<sup>1,3\*</sup>

6 **Running title:** Ecofriendly management of spot blotch of barley

7 <sup>1</sup>Department of Botany, Punjab Agricultural University, Ludhiana, Punjab, India.

8 <sup>2</sup>Department of Plant Pathology, Punjab Agricultural University, Ludhiana, Punjab, India.

9 <sup>3</sup>Department of Botany and Environmental Studies, DAV University, Jalandhar, Punjab, India.

10 \*Corresponding author; e-mail: [rohitchhabra325.rr@gmail.com](mailto:rohitchhabra325.rr@gmail.com); [rohit-bot@pau.edu](mailto:rohit-bot@pau.edu)

11  
12 **ABSTRACT**

13 **The objective of the current investigation was to examine the effects of botanically-**  
14 **induced resistance against the *Bipolaris sorokiniana* causing spot blotch disease in**  
15 **susceptible barley cultivar (PL 426). Different concentrations of botanical extracts**  
16 **prepared from leaf, fruit and bark of *Terminalia bellerica* and *Terminalia chebula* were**  
17 **tested against *B. sorokiniana* using poisoned food approach. The ethanolic and aqueous**  
18 **fruit extracts resulted in more than 70% mycelial inhibition of *B. sorokiniana*. The foliar**  
19 **spray of promising doses of botanical extracts was done 2 days prior to inoculation under**  
20 ***in-vivo* conditions. The physiological and biochemical variations were recorded after**  
21 **treatments from 1 to 7 days after treatment (DAT). Foliar spraying of botanical extracts**  
22 **resulted in an increase in total phenol content in inoculated barley plants from 1 DAT to**  
23 **7 DAT. The malondialdehyde content was significantly lower in plants treated with**  
24 **botanicals as compared to inoculated and uninoculated controls. The activity of**  
25 **peroxidase and phenylalanine ammonia lyase was significantly higher in all plants**  
26 **sprayed with botanical extracts as compared to controls. Furthermore, botanicals**  
27 **reduced the percentage of disease severity in treated plants while increasing the**  
28 **percentage of yield increase. Plants treated with *T. chebula* fruit extracts had the highest**  
29 **yield increase, followed by *T. bellerica* fruit extracts. From the present study, it can be**  
30 **concluded that the fruit extracts of *T. chebula* and *T. bellerica* are a promising approach**  
31 **for the eco-friendly management of spot blotch.**

32 **Keywords:** Barley, spot blotch, *Bipolaris sorokiniana*, extracts, resistance.

33  
34 **INTRODUCTION**

35 Barley (*Hordeum vulgare* L.) a member of the Poaceae, is one of the most versatile cereal  
36 crops, ranking fourth after wheat, maize and rice (Giraldo *et al.* 2019). It is a major dietary  
37 component of human beings and is also known as the poor man's crop as it requires low input

38 and has better adaptability to salinity, drought, alkalinity and marginal lands (Kaur *et al.*, 2021).  
39 It is grown during the rabi season in almost all parts of the world with arid or semi-arid climates  
40 (Golla, 2021). In recent years, fungal infections in cereals have been reported in various regions  
41 of the world and are considered to be one of the primary factors affecting yield and grain quality  
42 (Smagacz and Martyniuk, 2001). Plant diseases are abnormal conditions that primarily affect  
43 crop plants' primary and secondary metabolisms by disrupting their biochemical and  
44 physiological processes (Chhabra *et al.*, 2019). The most devastating fungal disease against  
45 barley is spot blotch caused by *Bipolaris sorokiniana* (Sacc.) Shoemaker, which produces  
46 irregular, oval, light to dark brown blotches on the leaf blade and sheath. These blotches later  
47 spread to cover the entire leaf surface (Kaur *et al.*, 2021). *B. sorokiniana* which is widespread  
48 throughout the world and is particularly aggressive in conditions of high relative humidity, high  
49 temperature and unbalanced soil fertility, annually causes significant economic losses in cereal  
50 harvests (Kumar *et al.*, 2002). Estimated yield losses as a result of spot blotch have been  
51 observed to range from 15.5% and may reach up to 100% under high disease incidence  
52 conditions (Kumar *et al.*, 2020).

53 In today's agricultural system, the need to produce high quality and quantity of grains per unit  
54 area is causing rapid changes in agricultural setup to meet the needs of an enormously growing  
55 population (Kaur *et al.*, 2023). The management of plant diseases heavily relies on fungicides.  
56 However, the excessive and inappropriate use of fungicides harms the ecosystem and has  
57 unintended impacts on plants and humans. Consequently, a sustainable approach to disease  
58 management is required, and biological control is one such secure and efficient approach that  
59 leads to the stimulation of induced resistance against the pathogen (Chhabra *et al.*, 2023c). In  
60 the present study, the *Terminalia* species were selected to determine their effectiveness against  
61 spot-blotch infection, as these are the most widely used medicines for traditional purposes  
62 worldwide (Cock, 2015). *Terminalia* is the second-largest genus in the Combretaceae family  
63 and consists of over 200 species. The plants in this genus have the highest level of genetic  
64 variety in South-East Asia, which is the original habitat for most of the world's tropical regions.  
65 (Das *et al.*, 2020). *Terminalia chebula* Retz. and *Terminalia bellirica* (Gaertn.) Roxb are highly  
66 adaptable botanical species, offering a distinct reservoir of many chemicals characterized by a  
67 wide range of chemical structures. Various *Terminalia* species possess nutraceutical properties  
68 that offer numerous health advantages, including the potential to treat certain disorders (Cock,  
69 2015). For instance, the fruits of *T. bellirica* (Gaertn.) Roxb. and *T. chebula* Retz. typically  
70 combine to create Triphala, a renowned polyherbal mixture used in Ayurvedic medicines. This  
71 plant contains many phytochemical bioactive rich compounds but the antifungal activities of

72 *Terminalia* species' fruit may be attributed to their elevated tannin content (Das *et al.*, 2020).  
73 Furthermore, the utilization of decoctions and macerations derived from the leaves and stem  
74 bark shown notable antibacterial efficacy (Abraham *et al.*, 2014). A total of sixty chemicals  
75 were detected in the leaf ethyl acetate extract, exhibiting significant antifungal properties. The  
76 compounds di-, tri-, and tetra-gallotannins, chebulinic acid and ellagitannins have been  
77 demonstrated to have antifungal effects (Salih *et al.*, 2022).

78 Plants produce reactive oxygen species as defense mechanism against different biotic stressors  
79 to initiate subsequent defence reactions (Asada, 2006). The induced defence mechanism  
80 consists of a variety of enzymatic and non-enzymatic components which form the antioxidant  
81 system of the host to act against the oxidative stress in crop plants which help the plant defend  
82 itself and increase its yield and productivity (Akter *et al.*, 2015). Moreover, secondary  
83 metabolism in plants which, includes the synthesis of numerous active metabolites, also protect  
84 the plants against different pathogens (Chhabra *et al.*, 2023b). Plant extracts reduce disease  
85 incidence by triggering host defense responses against the invading pathogen (Chhabra *et al.*,  
86 2023a). Plant extracts have the tendency to modulate physiological and biochemical  
87 mechanisms in order to make plants withstand stressful conditions. Several studies conducted  
88 by various researchers have demonstrated the protective nature of botanical extracts and their  
89 exogenous application, which make the plant resistant to invading pathogens (Chhabra *et al.*,  
90 2023a,b; Draz *et al.*, 2019; El-Malik and Abbas,2017). These extracts have the potential to alter  
91 the primary and secondary metabolisms, thereby improving the plant's photosynthetic capacity  
92 (Butt *et al.*, 2019).

93 The current study's main goal was to conduct *in-vitro* and *in-vivo* studies of *Terminalia*  
94 extracts against barley spot blotch disease. The present investigation was also conducted to  
95 assess the variations in antioxidant enzyme activities and non-enzymatic metabolites in treated  
96 barley plants as compared to control plants. This study can provide scientific basis to develop  
97 an eco-friendly management practices to eliminate the use of hazardous synthetic fungicides.

98

## 99 **MATERIALS AND METHODS**

### 100 **Plant material collection and drying**

101 Healthy and mature leaves, bark, and fruits (3 kg each) of *Terminalia chebula* (Harar) and  
102 *Terminalia bellerica* (Gaertn.) Roxb. (Bahera) were collected from trees ranging in age from  
103 11 to 13 years growing at the Research farm, Department of Forestry and Natural Resources,  
104 Punjab Agricultural University. The mature bark, fruits and leaves of *T. chebula* were collected  
105 in the months of October-December while the same plant parts of *T. bellerica* (Bahera) were

106 collected in May. To make fine powder from each plant material, the material was crushed in  
107 an electric grinder after being dried in a hot-air oven at 60°C for a week.

108

### 109 **Botanical Extracts preparation**

110 The aqueous and 50% ethanolic extracts of *Terminalia chebula* (Harar) and *Terminalia*  
111 *bellerica* (Bahera) were prepared by mixing dry powdered tissues (100mg/100ml) from each  
112 specified part in a 1:1 w/v solution of distilled water and fractionated 50% ethanolic solvent for  
113 48 hours. The extract was filtered through muslin cloth, centrifuged at 4000 rpm for 30 minutes,  
114 and later strained with Whatman No. 1 filter paper. The solution served as the crude extract  
115 (100 percent concentration) (Hossain *et al.*, 2011). Different concentrations from the crude  
116 extract were prepared to test their antifungal effect against the target pathogen.

117

### 118 **Fungal inoculum and *In-vitro* studies**

119 *Bipolaris sorokiniana* the causal organism, was procured from the Department of Plant  
120 Pathology Punjab Agricultural University which was used in this study. The identity of the  
121 pathogen was confirmed by observing its morphology and conidial characteristics under a light  
122 microscope. The pathogenicity of the culture was proven prior to experimentation using a  
123 highly susceptible cultivar and the fungi produced typical spot blotch symptoms after 3-4 days  
124 of inoculation.

125 The antifungal efficacy of botanicals was tested at concentrations of 10%, 20%, 30%, 40%  
126 and 50% on double strength PDA medium (Channakeshava and Pankaja, 2018). Botanical  
127 extracts were sterilised using 0.22-mm filters to evaluate their antifungal effect. To achieve the  
128 desired concentration, the necessary amount of each plant extract was added to double strength  
129 potato dextrose agar medium. The medium incorporated with botanicals served as treatments  
130 and the medium without botanical extracts was kept as a control. Three replications were  
131 performed for each concentration, and inoculated plates were then incubated at 25±2°C for 6  
132 days until mycelium growth covered the entire plate in the control plate. The percent inhibition  
133 of mycelial growth was calculated using the formula given by Vincent (1947).

134

### 135 **Crop establishment, Inoculation and disease assessment**

136 The seeds of the selected susceptible barley cultivar PL 426 procured from the Department of  
137 Plant Pathology were sown in the month of October using the standard package of practices  
138 followed by Punjab Agricultural University. The plot size was kept to 2×2 meters, and the total  
139 number of plots was 30, divided into three rows of ten plots each. The experiment was carried  
140 out in a randomised block design with three replications.

141 To multiply the pure culture of *B. sorokiniana*, tiny mycelial discs were transferred onto PDA-  
142 coated petri plates and incubated at  $24\pm 2^{\circ}\text{C}$  for a week. Spore suspension was developed for  
143 the disease's artificial inoculations. Conidia were collected from the fungus cultured in Petri  
144 dishes and utilized to prepare the conidial suspension. The fungal mycelium was stirred in  
145 sterile distilled water and then filtered through muslin fabric. The spore concentration of *B.*  
146 *sorokiniana* was adjusted to  $10^6$  spores/mL of sterile water using a haemocytometer. The  
147 botanical extracts that were found promising under laboratory conditions were evaluated  
148 against spot blotch disease of barley under field conditions. A foliar spray of selected botanical  
149 extracts of leaf, bark and fruit @ 50% concentration was given prior to the inoculation with  
150 pathogens in order for the host plants (at the booting stage) to develop resistance to the  
151 pathogen.

152 After one day of spraying botanical extracts, pathogen inoculation was performed. Plants were  
153 inoculated as the conidial suspension of *B. sorokiniana* ( $5\times 10^3$  conidia mL/L) was applied in  
154 the form of a fine mist to the leaves of each plant using an atomizer at noon. Polysorbate 20  
155 (1% w/v) was added to the sterile water to promote conidial adhesion. C1 was kept as an  
156 inoculated control that received no botanical treatment. C2 was kept as an untreated control  
157 (plants without inoculation and sprayed with sterile water). The plots were tagged with labels  
158 with information about the date of spray and inoculation. The disease symptom appeared in the  
159 form of minute spots on the leaves of the plant after the 4<sup>th</sup> day of inoculation. The physiological  
160 and biochemical variations were recorded after treatments from 1-7 days after treatment  
161 (Chhabra *et al.*, 2023a).

162

### 163 **Physiological and biochemical estimations**

164 The barley leaf samples collected from 1 DAT to 7 DAT were used to record the following  
165 metabolic variations in host plants. The chlorophyll concentration was determined  
166 spectrophotometrically according to the methodology of Hisox and Israeltam (1979). The  
167 phenol content was determined spectrophotometrically using standard methodology (Bray and  
168 Thorpe 1954). Malondialdehyde content was estimated using the standard procedure of  
169 Cheeseman (2006). The activity of peroxidase was determined spectrophotometrically  
170 according to the method of Shannon *et al.*, (1966). PAL activity was estimated using the  
171 standard methodology of Burrell and Rees (1974). To obtain an average value for the sample,  
172 each treatment was replicated three times.

173

174

## 175 **Disease and yield attributes**

176 The Terminal Disease Severity Index (DSI) was recorded and measured using a 0–9 double-  
177 digit scale as given by Saari and Presscott, (1975). The first digit of the scale denotes the percent  
178 blighted area on the flag leaf, whereas; the second digit represents the percent blighted area on  
179 the flag-1 (F-1) leaf. After the plants were harvested, they were dried, threshed, and recorded  
180 as the plot's yield. This yield was then converted to the unit of (q/ac) to calculate the total grain  
181 yield. The Ibrahim *et al.*, (2003) formula was used to determine the percent yield gain.

## 182 183 **Statistical analysis**

184 The field experiment used a randomised block design, and the lab experiment used a  
185 completely randomised design. The biochemical parameters were replicated thrice with  
186 identical results; the values presented in this manuscript represent the average of those results.  
187 The statistical analysis of the two-year pooled data was performed using Tukey's post hoc test  
188 through SPSS statistical software. The standard deviation of the means was calculated using  
189 Microsoft Excel (2016). At the probability level of ( $p \leq 0.05$ ), the differences were considered  
190 statistically significant (Easterling, 2015).

## 191 192 **RESULTS AND DISCUSSION**

### 193 ***In-vitro* screening of extracts presenting antifungal activity**

194 The effects of fruit, leaf and bark extracts (aqueous and 50% ethanolic) from *T. chebula* and *T.*  
195 *bellerica* were evaluated at 10%, 20%, 30%, 40% and 50% concentrations against *B.*  
196 *sorokiniana* fungal growth under *in-vitro* conditions. The colony diameter of the mycelium at  
197 the given concentrations of tested botanicals incorporated in PDA medium was noted until the  
198 growth of mycelium in the control covered the entire plate. Data regarding the antifungal  
199 efficacy of *Terminalia* extracts against *B. sorokiniana* growth is given in Table 1. At various  
200 doses, the tested botanicals effectively inhibited the growth of pathogens and thus showed  
201 significant antifungal efficacy (Figures 1 and 2). As the concentration of botanicals either in  
202 aqueous or ethanolic solvents increased, the mycelial inhibition (%) also increased.

203 On the basis of mean values, it was observed that among *T. chebula*, the fruit ethanol extract  
204 possessed significantly higher inhibitory potential (57.2%) against mycelial growth of fungal  
205 pathogens, followed by the fruit aqueous extract (54.5%). When compared to its bark extracts,  
206 a significant antifungal potential of 50.0% and 51.2% was recorded. Among the aqueous and  
207 50% ethanolic extracts of *T. chebula*, it was observed that the 50% ethanolic extract from all  
208 parts had significant inhibitory potential in contrast to its aqueous counterparts. The maximum

209 reduction in the fungal colony of *B. sorokiniana* was recorded for fruit treatments, followed by  
210 leaf treatments. In comparison to their other counterparts, the treatments with bark extracts  
211 proved to be less effective against the pathogen. Among aqueous and 50% ethanolic extracts of  
212 *T. bellerica*, it was observed that the 50% ethanolic extract from all parts had a significant  
213 inhibitory effect on fungal growth in contrast to its aqueous extracts.

214 Among all treatments, Harar fruit ethanolic extract, Harar bark aqueous extract, Bahera leaf  
215 aqueous extract and Bahera fruit ethanolic extract reported more than 50% inhibition of fungal  
216 colonies at 30%, 40% and 50% concentrations of botanicals, respectively. On comparing both  
217 medicinal plants, it was found that treatments with *T. chebula* possess more antifungal potential  
218 as compared to *T. bellerica* extracts. In contrast to aqueous extracts in all botanical treatments,  
219 ethanolic and aqueous extracts at the highest concentration (50%) from the selected *Terminalia*  
220 species inhibited fungal growth in PDA media. Tegegne *et al.* (2008) suggested *in vitro* tests of  
221 botanical extracts as an important step in selecting plants with antifungal potential against  
222 various plant pathogens. Naz *et al.* (2014) reported that methanolic and aqueous extracts  
223 of *Jacaranda mimosifolia* followed by *Thevetia peruviana* at different concentration caused  
224 significant inhibition of *B. sorokiniana* growth.

225

#### 226 **Altered Total chlorophyll content**

227 The data recorded for total chlorophyll content is presented in Table 2. All the plants sprayed  
228 with botanical extracts resulted in an increase in total chlorophyll content from the 1 DAT to  
229 the 7 DAT. Among treatments of *T. chebula*, in T2 (fruit ethanolic extract), the total chlorophyll  
230 content in the leaves of barley was significantly higher (4.13 mg g<sup>-1</sup> FW) than in plants with  
231 treatment T1 (fruit aqueous extract) of 3.32 mg g<sup>-1</sup> FW. The total chlorophyll contents of plots  
232 sprayed with bark aqueous (T3) and bark ethanolic extract (T4) were statistically at par to each  
233 other. Plants sprayed with *T. bellerica* fruit extracts (aqueous and ethanolic) had significantly  
234 higher chlorophyll content than (T8) plots sprayed with leaf aqueous extract (1.98 mg g<sup>-1</sup> FW)  
235 and (T7) leaf ethanolic treatment (1.61 mg g<sup>-1</sup> FW). The total chlorophyll content of the plants  
236 sprayed with the (T6) fruit ethanolic extract (3.14 mg g<sup>-1</sup> FW) and the (T5) fruit aqueous extract  
237 (2.87 mg g<sup>-1</sup> FW) was statistically at par. Among control treatments inoculated (without spray),  
238 C1 showed significantly lower total chlorophyll content in contrast to C2 uninoculated (water  
239 spray). Inoculated control (without spray) plots recorded a decrease in total chlorophyll content  
240 from the 2 DAT. On the basis of the mean data, it is clear that the plants sprayed with botanical  
241 extracts in all treatments, irrespective of the solvent, possessed significantly higher total  
242 chlorophyll content as compared to the control plants. Botanical-induced resistance refers to

243 increase in the synthesis of some compounds in plants that can inhibit the growth of pathogens  
244 as a result of high chlorophyll content as compared to untreated plants. The pathogen's toxic  
245 metabolites may be the reason for the decrease in chlorophyll content in inoculated plants  
246 (Senthil *et al.*, 2010) and they may prevent the production of chlorophyll rather than damage  
247 already-existing pigments (Mandal *et al.*, 2009). Similar results were recorded in the present  
248 study, where the inoculated control recorded the lowest chlorophyll content. Dallagnol *et al.*  
249 (2011) observed that the pathogen-produced compounds significantly decreased photosynthetic  
250 pigments, severely suppressing leaf photosynthesis in the process. This alters the physiology of  
251 the leaf and results in necrosis and cell death. Godlewska *et al.* (2021) reported that foliar  
252 applications of the plant extracts have led to an increase in the parameters like total yield,  
253 biomass, photosynthetic pigments, antioxidants and nutrient elements of radish.

254

### 255 **Modulation in Phenol Metabolism**

256 It is evident from the Table 3 that the uninoculated plants (C2) exhibited no significant  
257 variation in total phenol content and maintained a constant value throughout the investigation.  
258 Among treatments of *T. chebula*, treatment fruit ethanolic (T2) extract recorded an increase in  
259 phenol content of (25.0 mg g<sup>-1</sup> DW) followed by fruit aqueous spray T1 (24.7 mg g<sup>-1</sup> DW).  
260 Similarly, the plants treated with bark ethanolic extract also showed significantly higher  
261 phenolic content than their aqueous extract. Fruit extract treatments had significantly higher  
262 total phenols than bark extract treatments. Among treatments of *T. bellerica*, the fruit ethanolic  
263 extract (T6) recorded significantly high total phenols in contrast to the fruit aqueous spray (T5).  
264 But plots treated with leaf aqueous extract spray showed significantly lower phenol content  
265 (12.7 mg g<sup>-1</sup> DW) in contrast to T8 (16.2 mg g<sup>-1</sup> DW). Uninoculated plots (C2) had significantly  
266 higher total phenols than inoculated plots (C1). When compared to healthy and inoculated plots,  
267 all botanically sprayed plants accumulated significantly more total phenols. Spraying of  
268 botanical extracts resulted in an increase in total phenol content in inoculated barley plants until  
269 the last day of observation. The potential inhibitory effect of the plant extracts as potent bio-  
270 fungicides was in agreement with the findings of Karavaev *et al.* (2002), who showed that the  
271 activity of the aqueous extracts from the leaves of *Padus avium*, *Populus tremula*, *Chelidonium*  
272 *majus* significantly inhibited the *Puccinia triticina* infection and induced the systemic  
273 resistance in plants, which was attributed to the high level of total phenols in the treated leaves  
274 of wheat.

275

276



### 277 **Lipid peroxidation marker status: malondialdehyde**

278 The results of malondialdehyde content (MDA) obtained from Table 4 demonstrated that the  
279 spray of botanical extracts on inoculated plants significantly lowers the MDA content from the  
280 1 DAT till the last day of the observation recorded, whereas the inoculated control (C1)  
281 recorded significantly higher MDA content in contrast to plots sprayed with botanicals and  
282 uninoculated control (C2). Among the treatments of *Terminalia chebula*, the plots treated with  
283 bark extract hold significantly higher MDA content as compared to treatments with fruit  
284 (aqueous and ethanolic) extracts. The plants sprayed with fruit ethanolic extract (T2) and fruit  
285 aqueous extract (T1) were statistically equal to each other. Similarly, the plots sprayed with  
286 bark ethanolic extract (T4) and bark aqueous extract (T3) were statistically at par. Similarly,  
287 among the treatments of *Terminalia bellerica*, the leaf extracts recorded significantly higher  
288 MDA content in contrast to plots sprayed with fruit extracts. The plots treated with fruit  
289 ethanolic extract (T6) and fruit aqueous extract (T5) were statistically at par to each other.  
290 Inoculated plants without botanical spray (C1) had significantly higher MDA content than the  
291 uninoculated control (C2). In comparison to the inoculated and uninoculated control, all plots  
292 sprayed with botanical extracts had significantly lower MDA content. The lowering of cellular  
293 reactive oxygen species, which is essential for maintaining cell membrane integrity, is caused  
294 by the increased activities of scavenging antioxidant enzymes (Singh *et al.*, 2016). Similarly,  
295 Farag *et al.* (2011) found that willow aqueous extracts reduced the disease incidence of  
296 *Fusarium* wilt in tomato seedlings after 3 and 7 days of infection by increasing the activities of  
297 antioxidant defence enzymes and decreasing the level of malondialdehyde.

298

### 299 **Activity of Peroxidase (POX)**

300 The data on peroxidase activity in relation to plants treated with different botanicals are  
301 presented in Table 5. Among plants sprayed with *T. chebula*, the enzyme activity of fruit  
302 ethanolic extract (T2) and fruit aqueous extract (T1) were statistically at par to each other.  
303 Similarly, the activity in plants treated with bark ethanolic extract (T4) and bark aqueous extract  
304 (T3) was statistically at par. Among treatments of *T. bellerica* species, the enzyme activity of  
305 fruit ethanolic extract (T6) and fruit aqueous extract (T5) was statistically at par to each other.  
306 Similarly, the activity in plants treated with bark ethanolic extract (T8) and bark aqueous extract  
307 (T7) was statistically at par. Among both species, plants sprayed with fruit ethanolic extract  
308 recorded significantly higher peroxidase activity as compared to other botanical treatments.  
309 Among control treatments, uninoculated control (C2) resulted in significant high enzyme  
310 activity in contrast to inoculated control (C1). From the second day after pathogen (C1)

311 inoculation, the plants' enzymatic activity decreased dramatically. Peroxidase aids lignification  
312 by catalysing the final polymerization step of lignin synthesis, increasing tissue lignification  
313 and limiting fungi penetration (Barilli *et al.*, 2010). According to Geetha and Shetty report  
314 (2002), inducers upregulate the activity of peroxidase with correlated initiation of systemic  
315 resistance in host to confer fungal resistance. Similarly *Reynoutria sachalinensis* extracts  
316 provided protection against powdery mildew in cucumber and tobacco plants through  
317 modulation of antioxidant defense mechanisms (Sundar *et al.*, 2001).

318

### 319 **Activity of Phenyl alanine ammonia lyase (PAL)**

320 PAL is one of the foremost broadly examined proteins in plant secondary metabolism whose  
321 expression has also been proposed to play a significant role as a physiological marker for plant  
322 resistance assessment. The results of phenyl alanine ammonia lyase (PAL) activity are  
323 presented in Table 6. The increase in enzyme activity was significant from the first day after  
324 treatment to the seventh day in inoculated host plants sprayed with botanicals. Among the  
325 treatments of *T. chebula*, the plants treated with the fruit ethanolic extract (T2) showed  
326 significantly high PAL activity ( $6.05 \mu\text{g min}^{-1} \text{mg}^{-1} \text{protein}^{-1}$ ) followed by fruit aqueous extract  
327 (T1). The activity of plants sprayed with bark ethanolic extract (T4) and bark aqueous extract  
328 (T3) was statistically at par to each other. The spray of fruit extract recorded significantly higher  
329 PAL activity in comparison to plants sprayed with leaf extract. Among the treatments of *T.*  
330 *bellerica*, the PAL activity in plots sprayed with fruit ethanolic extract (T6) and fruit aqueous  
331 extract (T5) was statistically at par to each other. Similarly, the activity of plants treated with  
332 leaf ethanolic extract (T8) and leaf aqueous extract (T7) was statistically at par. Among both  
333 species, *T. chebula* had significantly higher PAL activity. Based on the mean data, it is clear  
334 that all of the plants treated with botanicals had significantly higher PAL activity than the  
335 inoculated and uninoculated control. According to Chakraboty *et al.*, (2007), spraying an  
336 aqueous extract of *Cathranthus roseus* to tea plants resulted in a significant increase in the  
337 expression of PR (pathogenesis-related) proteins as well as a quick build-up of phenolics in  
338 host plant both of which decreased the frequency of foliar blight. Subsequent rise in PAL  
339 activity and phenolics leads to upregulation in endogenous salicylic acid biosynthesis, an  
340 essential plant systemic resistance signal (Chhabra *et al.*, 2022)

341

### 342 **Terminal Disease severity**

343 Table 7 displayed data on the effect of botanical extracts on disease severity and disease  
344 control percentage. From the table, it can be noted that the highest terminal disease severity was

345 recorded in control plants, which received only pathogen inoculation (69.6%). All the  
346 botanically treated plants led to lower terminal disease severity as compared to the inoculated  
347 control plants. Among the plants sprayed with extracts of *T. chebula* species, the significant  
348 lesser terminal disease severity percent was observed with treatment of *T. chebula*, especially  
349 treatment T2 which led to greater yield and percent disease control. Among *T. bellerica*, the  
350 treatment with a leaf ethanolic extract recorded a significantly lower disease severity of 39%  
351 with a percent disease control of 58.4%. Among all botanically treated plots, the leaf aqueous  
352 extract of *T. bellerica* resulted in significantly high terminal disease severity and lower disease  
353 control. Amongst the plants treated with aqueous and ethanolic extracts of fruits from both  
354 species, the ethanolic treatments of both *Terminalia* species showed a significantly higher  
355 percentage of disease control in contrast to the aqueous treatments. Due to the high similarity  
356 between the phytochemistry of both tree species, it is presumed that the mechanism of action  
357 of their antifungal properties is strongly similar (Zhang *et al.*, 2019). However, further studies  
358 are required to better understand the molecular and cellular mechanisms behind the antifungal  
359 roles of botanical extracts.

360

#### 361 **Total Yield**

362 It is evident from the data (Table 7) that the yield component recorded was significantly higher  
363 in plants sprayed with different botanical extracts when compared with controls, thus  
364 demonstrating their protective nature by inducing resistance against pathogens. Among  
365 treatments, the maximum percent increase in yield and total yield were recorded in plots treated  
366 with (T2) fruit ethanolic extract of *T. chebula* (i.e., 42.4% and 13.9q/ac, respectively), followed  
367 by (T1) plants sprayed with fruit aqueous extract. The treatment of fruit ethanolic and aqueous  
368 extract from *T. bellerica* recorded a significant increase in total yield in contrast to leaf aqueous  
369 and ethanolic extract. The plants treated with *T. chebula* and *T. bellerica* resulted in a significant  
370 increase in yield compared to control C1 (water sprayed with pathogen spore suspension).  
371 Wheat leaf rust severity was reduced considerably by foliar spraying of pomegranate,  
372 eucalyptus, cactus, garlic and neem plant extracts (El-Malik and Abbas, 2017). Foliar  
373 applications of these extracts not only impart resistance in infected plants but also increased  
374 yield and grain quality. The results obtained are in accordance with Kumar *et al.*, (2017), who  
375 found that the foliar application of *Lantana camara* extract to potato plants as an inducer before  
376 the inoculation with *Alternaria solani* led to a reduction in the disease severity. Wheat leaf rust  
377 severity was reduced considerably by foliar spraying of different plant extracts (El-Malik and  
378 Abbas, 2017). Draz *et al.* (2019) demonstrated that treating *Puccinia triticina*-infected wheat

379 plants with the investigated plant extracts (*Melia azedarach*, *Acalypha wilkesiana*, *Lawsonia*  
380 *inermis*, *Punica granatum* and *Lantana camara*) significantly improved yield components  
381 when compared to the untreated control.

382 In conclusion, the current study's findings clearly demonstrated that these extracts were  
383 efficient against barley spot blotch pathogen. The mechanism by which botanical extracts work  
384 differ from those of traditional pesticides in that, they restrict its growth both directly and  
385 indirectly by eliciting defense mechanisms from plants. In the current context of sustainable  
386 agriculture and rising consumer demand for organic food, plant resistance inducers are seen as  
387 a potential and environmentally acceptable alternative to conventional fungicides. It is therefore  
388 highly advised to incorporate them into eco-friendly disease management strategy.

389

### 390 **ACKNOWLEDGEMENTS**

391 The authors are thankful to the Head, Department of Botany and Plant Pathology, for  
392 providing the required research facilities for the conduct of this investigation.

393

### 394 **REFERENCES**

395 Abraham, A., Mathew, L. and Samuel, S. 2014. Pharmacognostic Studies of the Fruits of  
396 *Terminalia bellirica* (Gaertn.) Roxb. *J. Pharmacognosy. Phytochem.*, **3**: 45–52.

397 Akter, S., Huang, J., Waszczak, C., Jacques, S., Gevaert, K. and Breusegem, F.V. 2015.  
398 Cysteines under ROS Attack in Plants: A Proteomics View. *J. Exp. Bot.*, **66**: 2935–2944.

399 Ali, S., Ganai, B. A., Kamili, A.N., Bhat, A. A., Mir, Z. A., Bhat, J. A., Tyagi, A., Islam, S.  
400 T., Mushtaq, M., Yadav, P. and Rawat, S. 2018. Pathogenesis-Related Proteins and Peptides as  
401 Promising Tools for Engineering Plants with Multiple Stress Tolerance. *Microbiol. Res.*, **212**:  
402 29-37.

403 Asada, K. 2006. Production and Scavenging of Reactive Oxygen Species in Chloroplasts and  
404 their Functions. *Plant. Physiol.*, **41(2)**: 391-6.

405 Barilli, E., Prats, E. and Rubiales, D. 2010. Benzothiadiazole and BABA Improve Resistance  
406 to *Uromyces pisi* (Pers.) Wint. in *Pisum sativum* L. with an Enhancement of Enzymatic  
407 Activities and Total Phenolic Content. *Eur. J. Pl. Pathol.*, **128**: 483-93.

408 Bray, H. G. and Thorpe, W. 1954. Analysis of Phenolic Compounds of Interest in Metabolism.  
409 *Meth. Biochem. Anal.*, **1**: 27-52

410 Burrell, M. M. and Rees, T. A. P. 1974. Metabolism of Phenylalanine and Tyrosine by Rice  
411 Leaves Infected by *Pyricularia oryzae*. *Physiol. Pl. Pathol.*, **4**: 497-508

- 412 Butt, U. R., Naz, R., Nosheen, A., Yasmin, H., Keyani, R., Hussain, I. and Hassan, M. N.  
413 2019. Changes in Pathogenesis-Related Gene Expression in Response to Bioformulations in  
414 the Apoplast of Maize Leaves against *Fusarium oxysporum*. *J. Plant. Interact.*, **14(1)**: 61-72.
- 415 Chakraborty, B. N., Biswas, R. D. and Sharma, M. 2007. Induction of Resistance in Tea Plants  
416 against *Alternaria alternata* by Foliar Application of Leaf Extracts. *J. Mycol. Pl. Pathol.*, **37(1)**:  
417 60-64.
- 418 Channakeshava, C. and Pankaja, N. S. 2018. *In-vitro* Evaluation of Fungicides, Plant Extracts  
419 and Biocontrol Agents against Brown Leaf Spot of Paddy. *Int. J. Curr. Microbiol. App. Sci.*,  
420 **7**:127–132.
- 421 Cheeseman, J. M. 2006. Hydrogen Peroxide Concentrations in Leaves under Natural  
422 Conditions. *J. Exp. Bot.*, **57**: 2435–44.
- 423 Chhabra, R., Kaur, N. and Bala, A. 2019. Physiological and Biochemical Alterations Imposed  
424 by *Fusarium fujikuroi* Infection in Aromatic and Non-Aromatic Rice Cultivars. *Pl. Physiol.*  
425 *Rep.*, **24**: 563-575.
- 426 Chhabra, R., Sharma, R., Hunjan, M. S. and Sharma, P. 2023a. Foliar Spray of Botanical  
427 Extracts Influences Biochemical Processes and Plant Defense Enzymes to Ameliorate Brown  
428 Spot Induced Yield Loss in Rice. *Eur. J. Plant Pathol.*, 1-17.
- 429 Chhabra, R., Sharma, R., Hunjan, M. S., Sharma, V. K., Thakur, S. and Chauhan, S. 2022.  
430 Physio-biochemical and Histological Alterations in response to Sheath Blight Disease of Rice  
431 (*Oryza sativa* L.). *J Phytopathol.*, **170**: 778-790.
- 432 Chhabra, R., Sharma, R., Hunjan, M. S., Sharma, V. K., Thakur, S. and Chauhan, S. 2023b.  
433 Efficacy of Botanical Extracts on Imparting Systemic Acquired Resistance Against Rice Sheath  
434 Blight Incited by *Rhizoctonia solani*. *J. Plant. Dis. Prot.*, **130**: 551–569.
- 435 Chhabra, R., Sharma, R., Hunjan, M. S., Sharma, V. K., Thakur, S. and Chauhan, S. 2023c.  
436 Phytochemical Characterization and Antifungal Ability of Three Meliaceae Species Against  
437 *Bipolaris oryzae*. *Agric. Res. J.*, **60(1)**:146-152.
- 438 Cock, I. 2015. The Medicinal Properties and Phytochemistry of Plants of the  
439 Genus *Terminalia* (Combretaceae). *Inflammopharmacology.*, **23**: 203–29.
- 440 Dallagnol, L. J., Rodrigues, F. A., Martins, S. C. V., Cavatte, P. C. and Damatta, F. M.  
441 2011. Alterations on Rice Leaf Physiology during Infection by *Bipolaris oryzae*. *Australasian.*  
442 *Pl. Pathol.*, **40**: 360–365.
- 443 Das, G., Kim, D-Y., Fan, C., Gutierrez-Grijalva, E. P., Heredia, J. B., Nissapatorn, V.,  
444 Mitsuwan, W., Pereira, M. L., Nawaz, M., Siyadatpanah, A., Norouzi, R., Sawicka, B., Shin,

- 445 H-S. and Patra, J. K. 2020. Plants of the Genus *Terminalia*: An Insight on Its Biological  
446 Potentials, Pre-Clinical and Clinical Studies. *Front. Pharmacol.*, **11**: 561248.
- 447 Draz, I. S., Elkhwaga, A. A., Elzaawely, A. A., Elzahaby, H. M. and Ismail, A. A. 2019.  
448 Application of Plant Extracts as Inducers to Challenge Leaf Rust of Wheat. *Egypt. J. Biolog.*  
449 *Pest. Control.*, **29**: 6.
- 450 Easterling, Robert. G 2015. Fundamentals of Statistical Experimental Design and Analysis.  
451 John Wiley & Sons, USA.
- 452 El-Malik, N. I. and Abbas, I. K. 2017. Evaluation of Certain Plant Extracts for the Control of  
453 Wheat Leaf Rust Disease. *Egypt. J. Biolog. Pest. Control.*, **27**: 23-33.
- 454 Farag, H. R. M., Abdou, A Z., Salama, D. A., Ibrahim, M. A. R. and Srour, H. A. M. 2011.  
455 Effect of Neem and Willow Aqueous Extracts as *Fusarium* wilt Disease in Tomato Seedlings:  
456 Induction of Antioxidant Defensive Enzymes. *Ann. Agric. Sci.*, **56**: 1-7.
- 457 Geetha, H. M. and Shetty, H. S. 2002. Induction of Resistance in Pearl Millet against Downy  
458 Mildew Disease caused by *Sclerospora graminicola* using Benzothiadiazole, Calcium Chloride  
459 and Hydrogen Peroxide—A Comparative Evaluation. *Crop. Prot.*, **21(8)**: 601-610.
- 460 Giraldo, P., Benavente, E., Manzano-Agugliaro, F. and Gimenez, E. 2019. Worldwide  
461 Research Trends on Wheat and Barley: A Bibliometric Comparative Analysis. *Agronomy.*, **9**:  
462 352.
- 463 Godlewska, K., Pacyga, P., Michalak, I., Biesiada, A., Szumny, A., Pachura, N. and Piszcz,  
464 U. 2021. Systematic Investigation of the Effects of Seven Plant Extracts on the Physiological  
465 Parameters, Yield, and Nutritional Quality of Radish (*Raphanus sativus* var. *sativus*). *Front.*  
466 *Plant Sci.*, **12**: 651152
- 467 Golla, B. 2021. Agricultural Production System in Arid and Semi-Arid Regions. *J. Agric. Sc.*  
468 *Food. Technol.*, **7(2)**: 234-244.
- 469 Hisox, J. D. and Israelstam, G. F. 1979. A Method for the Extraction of Chlorophyll From the  
470 Leaf Tissues Without Maceration. *Can. J. Bot.*, **51**: 1332-34.
- 471 Hossain, M. A. and Nagooru, M. R. 2011. Biochemical Profiling and Total Flavonoids  
472 Contents of Leaves Crude Extract of Endemic Medicinal Plant *Corydiline terminalis* L. Kunth.  
473 *Pharmacogn. J.*, **3(24)**: 25-30.
- 474 Ibrahim, A. S., Khafagi, Y. S., Ghanim, A. M. and EL-Abbasi, I. H. 2003. Integrated  
475 Management of Powdery Mildew on Cantaloupe. *Egypt. J. Appl. Sci.*, **18**: 521–531.
- 476 Karavaev, V. A., Solntsev, M. K., Kuznetsov, A.M., Polyakova, I. B., Frantsev, V.V., Yurina,  
477 E. V., Yurina, T. P., Taborsky, V., Polak, J., Lebeda, A. and Kudela, V. 2002. Plant Extracts as

478 the Source of Physiologically Active Compounds Suppressing the Development of Pathogenic  
479 Fungi. *Pl. Protect. Sci.*, **38**: 200–204.

480 Kaur, A., Chhabra, R., Sharma, R., Sharma, V. K., Sharma, P. and Khattar, N. 2023. Botanical  
481 Extracts: A Step Towards Eco-friendly Pest Management Strategy. *Agric. Res. J.*, **60**(2): 167-  
482 176.

483 Kaur, A., Sharma, V. K. and Sharma, S. 2021. Management of Spot Blotch of Barley: An  
484 Eco-friendly Approach. *Austr. Pl. Pathol.*, **50**: 389–401.

485 Kumar, J., Schafer, P., Huckelhoven, R., Langen, G., Baltruschat, H., Stein, E., Nagarajan, S.  
486 and Kogel, K. H. 2002. *Bipolaris sorokiniana*, A Cereal Pathogen of Global Concern:  
487 Cytological and Molecular Approaches Towards Better Control. *Mol. Plant. Pathol.*, **3**(4):185–  
488 95.

489 Kumar, S., Kumar, N., Prajapati, S. and Maurya, S. 2020. Review on Spot Blotch of Wheat:  
490 An Emerging Threat to Wheat Basket in Changing Climate. *J. Pharmacogn. Phytochem.*, **9**:  
491 1985–1997.

492 Kumar V, Biswas, S. K., Lal, K., Nagar, D. and Tilak Chowdary, V. 2017. Induced Resistance  
493 in Potato against Early Blight caused by *Alternaria solani* (Sorauer) Through Plant Extracts as  
494 Inducer. *Int. J. Curr. Microbiol. App. Sci.*, **6**(8): 1888-98.

495 Kumar, V., Singh, G. and Tyagi, A. 2017. Evaluation of Different Fungicides Against  
496 *Alternaria* Leaf Blight of Tomato (*Alternaria solani*) *Int. J. Curr. Microbiol. App. Sci.*, **6**(5):  
497 2343-2350.

498 Mandal, K., Saravanan, R., Maiti, S. and Kothari, L. L. 2009. Effect of Downy Mildew  
499 Disease on Photosynthesis and Chlorophyll Fluorescence in *Plantago ovata* Forsk. *J. Plant.*  
500 *Dis. Prot.*, **116**:164–168.

501 Naz, R., Bano, A., Wilson, N. L., Guest, D. and Roberts, T. H. 2014. Pathogenesis-related  
502 Protein Expression in the Apoplast of Wheat Leaves Protected against Leaf Rust Following  
503 Application of Plant Extracts. *Phytopathology.*, **104**: 933–44.

504 Saari, E. E. and Prescott, J. M. 1975. A Scale for Appraising the Foliar Intensity of Wheat  
505 Disease. *Plant. Dis. Rep.*, **59**: 377–380.

506 Salih, E. Y. A., Julkunen-Tiitto, R., Luukkanen, O., Fyhrqvist, P. 2022. Anti-Candida Activity  
507 of Extracts Containing Ellagitannins, Triterpenes and Flavonoids of *Terminalia brownii*, a  
508 Medicinal Plant Growing in Semi-Arid and Savannah Woodland in Sudan. *Pharmaceutics.*,  
509 **14**(11): 2469.

510 Senthil, V., Ramasamy, P., Elaiyaraja, C. and Elizabeth, A. R. 2010. Some Phytochemical  
511 Properties Affected by the Infection of Leaf Spot Disease of *Cucumis sativus* L. caused by  
512 *Penicillium notatum*. *Afr. J. Basic Appl. Sci.*, **2**:64-70.

513 Shannon, L. M., Kay, E. and Lew, J. Y. 1966. Peroxidase Isozymes from Horse Radish Roots:  
514 Isolation and Physical Properties. *J. Biol. Chem.*, **241**: 2166-72.

515 Singh, U. B, Malviya, D., Singh, S., Imran, M., Pathak, N., Alam, M., Rai, J. P., Singh, R. K.,  
516 Sarma, B. K., Sharma, P. K. and Sharma, A. K. 2016. Compatible Salt-tolerant Rhizosphere  
517 Microbe-mediated Induction of Phenylpropanoid Cascade and Induced Systemic Responses  
518 against *Bipolaris sorokiniana* (Sacc.) Shoemaker Causing Spot Blotch Disease in Wheat  
519 (*Triticum aestivum* L.). *Appl. Soil Ecol.*, **108**: 300-306.

520 Smagacz, J. and Martyniuk, S. 2001. Infection of the Stalk Base and Roots of Winter Wheat  
521 Grown After Various Forecrops by Pathogens, with Particular Emphasis on *Gaeumannomyces*  
522 *graminis*. *Prog. Plant. Prot.*, **4**:745-746

523 Sundar, R. A., Velazhahan, R., Viswanathan, R., Padmanaban, P. and Vidhyasenkarana, P.  
524 2001. Induction of Systemic Resistance to *Colletotrichum falcatum* in Sugarcane by a Synthetic  
525 Signal Molecule, Acibenzolar-s-methyl (CGA-245704). *Phytoparasitica* **29**: 231-42.

526 Tegegne, G., Pretorius J.C. and Swart W. J. 2008. Antifungal Properties of *Agapanthus*  
527 *africanus* L Extracts Against Plant Pathogens. *Crop. Prot.*, **27**: 1052-60.

528 Vincent, J. M. 1947. Distribution of Fungal Hyphae in the Presence of Certain Inhibition.  
529 *Nature.*, **150**: 850.

530 Zhang, X. R., Kaunda, J. S., Zhu, H. T., Wang, D., Yang, C.R. and Zhang, Y. J. 2019. The  
531 Genus *Terminalia* (Combretaceae): An Ethnopharmacological, Phytochemical and  
532 Pharmacological Review. *Nat. Prod. Bioprospect.*, **9(6)**: 357-392.

533

534

535

536

537

538

539

540

541

542



543 **Table 1.** Inhibitory effect of botanical extracts at different concentration against *B. sorokiniana*  
 544 under *in-vitro* conditions.

| Tree species  | Plant part | Solvent       | Mycelial inhibition (%) |                   |                   |                   |                   | Mean               |
|---|------------|---------------|-------------------------|-------------------|-------------------|-------------------|-------------------|--------------------|
|   |            |               | 10 %                    | 20 %              | 30 %              | 40 %              | 50 %              |                    |
| Concentration tested (%)  |            |               | 10 %                    | 20 %              | 30 %              | 40 %              | 50 %              |                    |
| <i>Terminalia chebula</i> (Harar)   | Fruit      | Aqueous       | 33.2±1.3                | 39.8±1.5          | 44.0±1.2          | 70.7±1.6          | 84.7±0.7          | 54.5 <sup>b</sup>  |
|   | Fruit      | 50% Ethanolic | 32.9±1.2                | 39.4±0.6          | 52.0±1.5          | 74.9±2.4          | 86.8±0.5          | 57.2 <sup>a</sup>  |
|   | Leaf       | Aqueous       | 26.3±2.9                | 27.4±1.0          | 28.4±1.5          | 30.2±2.4          | 41.0±1.5          | 29.7 <sup>i</sup>  |
|   | Leaf       | 50% Ethanolic | 30.0±1.5                | 43.1±1.6          | 49.5±0.7          | 54.1±1.2          | 56.6±0.9          | 46.6 <sup>e</sup>  |
|   | Bark       | Aqueous       | 18.4±1.8                | 33.1±0.9          | 60.6±1.5          | 62.8±1.1          | 75.2±0.6          | 50.1 <sup>de</sup> |
|   | Bark       | 50% Ethanolic | 30.0±1.6                | 37.0±0.7          | 41.0±2.7          | 69.1±0.8          | 78.7±0.9          | 51.2 <sup>cd</sup> |
| Mean  |            |               | 28.5                    | 35.9              | 45.9              | 60.6              | 70.2              |                    |
| <i>Terminalia bellerica</i> (Bahera)  | Fruit      | Aqueous       | 21.2±1.2                | 30.4±0.9          | 49.5±1.5          | 77.0±0.6          | 85.7±1.2          | 52.8 <sup>bc</sup> |
|   | Fruit      | 50% Ethanolic | 41.7±1.7                | 44.7±1.2          | 50.8±1.2          | 58.9±0.5          | 71.0±2.2          | 53.4 <sup>bc</sup> |
|   | Leaf       | Aqueous       | 26.7±1.8                | 19.4±0.6          | 54.3±1.6          | 66.5±0.6          | 69.1±1.0          | 47.2 <sup>fg</sup> |
|   | Leaf       | 50% Ethanolic | 29.6±1.2                | 35.9±1.8          | 41.5±1.4          | 57.4±1.3          | 79.5±0.8          | 48.8 <sup>ef</sup> |
|   | Bark       | Aqueous       | 7.84±0.7                | 12.2±0.7          | 32.9±0.7          | 34.3±1.3          | 38.5±1.5          | 25.1 <sup>j</sup>  |
|   | Bark       | 50% Ethanolic | 28.4±1.4                | 32.3±0.7          | 40.4±1.8          | 40.6±0.8          | 63.8±3.0          | 41.1 <sup>h</sup>  |
| Mean  |            |               | 25.9                    | 29.1              | 44.9              | 55.8              | 67.9              |                    |
| Overall Mean  |            |               | 27.2 <sup>d</sup>       | 32.6 <sup>d</sup> | 45.4 <sup>c</sup> | 58.2 <sup>b</sup> | 69.0 <sup>a</sup> | 46.5               |
| Propiconazole at 0.1% concentration exhibited 100% mycelial growth inhibition                               |            |               |                         |                   |                   |                   |                   |                    |
| Mean±SD, each value with different letter is significantly different (p≤0.05) as per Tukey's post hoc test. |            |               |                         |                   |                   |                   |                   |                    |

545

546 **Table 2.** Effect of foliar spray of botanical extracts on total chlorophyll content of barley.

| Tree species   | Spray                 | Treatment | Total chlorophyll content (mg g <sup>-1</sup> FW) |                    |                    |                   |                    |                   |                   | MEAN               |
|--|-----------------------|-----------|---|--------------------|--------------------|-------------------|--------------------|-------------------|-------------------|--------------------|
|  |                       |           | 1 DAT   | 2 DAT              | 3 DAT              | 4 DAT             | 5 DAT              | 6 DAT             | 7 DAT             |                    |
| <i>T. chebula</i>  | Fruit (aqueous)       | T1        | 2.77±1.6  | 2.86±0.5           | 2.94±0.2           | 3.42±0.3          | 3.56±0.7           | 3.74±0.9          | 3.97±0.4          | 3.32 <sup>b</sup>  |
|  | Fruit (50% ethanolic) | T2        | 3.12±0.1  | 3.59±0.9           | 3.86±0.3           | 4.15±0.6          | 4.63±0.6           | 4.76±0.9          | 4.85±0.3          | 4.13 <sup>a</sup>  |
|  | Bark (aqueous)        | T3        | 1.60±0.1  | 1.66±0.8           | 1.79±0.3           | 1.94±0.3          | 2.03±0.5           | 2.12±0.2          | 2.19±0.2          | 1.90 <sup>cd</sup> |
|  | Bark (50% ethanolic)  | T4        | 1.84±0.2  | 1.93±0.2           | 1.98±0.6           | 2.27±0.6          | 2.36±0.9           | 2.48±0.7          | 2.54±0.5          | 2.2 <sup>c</sup>   |
| Mean   |                       |           | 2.33  | 2.51               | 2.64               | 2.94              | 3.14               | 3.28              | 3.39              |                    |
| <i>T. bellerica</i>  | Fruit (aqueous)       | T5        | 2.31±0.4  | 2.42±0.6           | 2.63±0.3           | 3.04±0.2          | 3.15±0.4           | 3.29±0.8          | 3.48±0.6          | 2.87 <sup>b</sup>  |
|  | Fruit (50% ethanolic) | T6        | 2.68±0.2  | 2.74±0.1           | 2.89±0.2           | 3.27±0.5          | 3.34±0.4           | 3.46±0.4          | 3.58±0.1          | 3.14 <sup>b</sup>  |
|  | Leaf (aqueous)        | T7        | 1.27±0.5  | 1.36±0.1           | 1.49±0.3           | 1.56±0.5          | 1.79±0.6           | 1.86±0.3          | 1.93±0.3          | 1.61 <sup>de</sup> |
|  | Leaf (50% ethanolic)  | T8        | 1.42±0.1  | 1.59±0.6           | 1.74±0.1           | 2.09±0.6          | 2.16±0.3           | 2.29±0.7          | 2.57±0.4          | 1.98 <sup>cd</sup> |
| Mean   |                       |           | 1.92  | 2.02               | 2.19               | 2.49              | 2.61               | 2.72              | 2.89              |                    |
| Inoculated (without spray)   |                       | C1        | 0.56±0.4  | 0.85±0.2           | 0.75±0.2           | 0.54±0.1          | 0.58±0.1           | 0.42±0.7          | 0.36±0.6          | 0.58 <sup>f</sup>  |
| Uninoculated (water spray)   |                       | C2        | 1.04±0.4  | 1.09±0.6           | 1.13±0.4           | 1.25±0.4          | 1.31±0.4           | 1.26±0.6          | 1.12±0.8          | 1.17 <sup>e</sup>  |
| Overall Mean   |                       |           | 1.86 <sup>c</sup>                                 | 2.01 <sup>bc</sup> | 2.12 <sup>bc</sup> | 2.35 <sup>b</sup> | 2.49 <sup>ab</sup> | 2.57 <sup>a</sup> | 2.66 <sup>a</sup> |                    |
| Mean±SD, each value with different letter is significantly different (p ≤ 0.05) as per Tukey's post hoc test; DAT refers to days after treatment |                       |           |   |                    |                    |                   |                    |                   |                   |                    |

547

548

549

550

551

**Table 3.** Effect of foliar spray of botanical extracts on total phenol content of barley.

| Total Phenol content (mg g <sup>-1</sup> DW) |                       |           |                    |                    |                     |                    |                   |                    |                   |                   |
|--|-----------------------|-----------|--------------------|--------------------|---------------------|--------------------|-------------------|--------------------|-------------------|-------------------|
| Tree species                                 | Spray                 | Treatment | 1 DAT              | 2 DAT              | 3 DAT               | 4 DAT              | 5 DAT             | 6 DAT              | 7 DAT             | MEAN              |
| <i>T. chebula</i>                            | Fruit (aqueous)       | T1        | 19.6±0.7           | 23.4±0.5           | 25.7±0.6            | 26.1±0.9           | 26.5±0.4          | 26.8±0.9           | 26.6±0.7          | 24.7 <sup>a</sup> |
|  | Fruit (50% ethanolic) | T2        | 22.3±0.4           | 23.2±0.7           | 23.4±0.2            | 25.6±0.9           | 27.8±0.7          | 27.9±0.7           | 26.7±0.9          | 25.0 <sup>a</sup> |
|  | Bark (aqueous)        | T3        | 13.3±0.7           | 14.1±0.6           | 14.5±0.2            | 15.2±0.8           | 16.1±0.7          | 16.7±0.7           | 17.0±0.9          | 15.0 <sup>d</sup> |
|  | Bark (50% ethanolic)  | T4        | 15.1±0.5           | 15.3±0.5           | 16.1±0.5            | 17.3±0.6           | 17.9±0.8          | 18.4±0.4           | 19.2±0.5          | 16.8 <sup>c</sup> |
| Mean   |                       |           | 17.6               | 19.0               | 20.0                | 21.0               | 22.1              | 22.5               | 20.4              |                   |
| <i>T. bellerica</i>                          | Fruit (aqueous)       | T5        | 15.9±0.6           | 16.2±0.8           | 16.6±0.7            | 17.2±1.1           | 18.4±0.7          | 19.0±0.5           | 18.2±0.8          | 17.1 <sup>c</sup> |
|  | Fruit (50% ethanolic) | T6        | 18.5±0.7           | 19.3±0.5           | 19.5±0.5            | 20.1±1.1           | 20.7±0.7          | 21.1±0.5           | 21.8±0.8          | 19.9 <sup>b</sup> |
|  | Leaf (aqueous)        | T7        | 11.3±0.8           | 11.6±0.7           | 12.1±0.6            | 13.4±0.7           | 13.9±0.5          | 14.2±0.5           | 14.3±0.9          | 12.7 <sup>e</sup> |
|  | Leaf (50% ethanolic)  | T8        | 14.1±1.0           | 14.6±0.6           | 16.5±0.9            | 16.9±0.5           | 17.1±0.2          | 17.2±0.7           | 18.6±1.0          | 16.2 <sup>c</sup> |
| Mean   |                       |           | 14.9               | 15.4               | 16.2                | 17.0               | 17.5              | 17.9               | 16.2              |                   |
| Inoculated (without spray)                   |                       | C1        | 6.3±0.4            | 8.2±0.6            | 7.1±0.5             | 6.4±0.6            | 4.7±0.4           | 3.6±0.4            | 2.9±0.5           | 5.60 <sup>g</sup> |
| Uninoculated (water spray)                   |                       | C2        | 9.8±0.6            | 9.1±0.4            | 8.9±0.6             | 9.3±0.3            | 8.5±0.2           | 8.6±0.2            | 9.2±0.3           | 8.9 <sup>f</sup>  |
| Overall Mean                                 |                       |           | 14.6 <sup>cd</sup> | 15.5 <sup>cd</sup> | 16.0 <sup>bcd</sup> | 16.8 <sup>bc</sup> | 17.1 <sup>b</sup> | 17.4 <sup>ab</sup> | 18.2 <sup>a</sup> | 17.8              |

Mean±SD, each value with different letter is significantly different ( $p \leq 0.05$ ) as per Tukey's post hoc test; DAT refers to days after treatment.

552

553

**Table 4.** Effect of foliar spray of botanical extracts on malondialdehyde content of barley.

| Malondialdehyde content (nM g <sup>-1</sup> FW) |                       |           |                   |                    |                     |                    |                   |                   |                   |                   |
|---|-----------------------|-----------|-------------------|--------------------|---------------------|--------------------|-------------------|-------------------|-------------------|-------------------|
| Tree species                                    | Spray                 | Treatment | 1 DAT             | 2 DAT              | 3 DAT               | 4 DAT              | 5 DAT             | 6 DAT             | 7 DAT             | MEAN              |
| <i>T. chebula</i>                               | Fruit (aqueous)       | T1        | 1.95±0.5          | 1.86±0.8           | 1.72±0.4            | 1.63±0.4           | 1.51±0.3          | 1.50±0.8          | 1.33±0.5          | 1.64 <sup>c</sup> |
|   | Fruit (50% ethanolic) | T2        | 1.84±1.2          | 1.76±0.5           | 1.53±0.3            | 1.47±1.1           | 1.41±0.6          | 1.26±0.3          | 1.19±0.6          | 1.49 <sup>c</sup> |
|   | Bark (aqueous)        | T3        | 2.59±1.3          | 2.51±0.2           | 2.39±0.3            | 2.34±0.6           | 2.22±0.2          | 2.15±0.6          | 2.08±0.4          | 2.32 <sup>b</sup> |
|   | Bark (50% ethanolic)  | T4        | 2.43±0.5          | 2.36±0.1           | 2.31±0.4            | 2.25±0.1           | 2.14±0.6          | 2.02±0.2          | 1.97±1.0          | 2.21 <sup>b</sup> |
| Mean  |                       |           | 2.20              | 2.12               | 1.98                | 1.92               | 1.82              | 1.73              | 1.64              |                   |
| <i>T. bellerica</i>                             | Fruit (aqueous)       | T5        | 2.07±0.8          | 2.01±0.2           | 1.89±0.4            | 1.84±0.2           | 1.76±1.1          | 1.71±0.5          | 1.56±0.2          | 1.84 <sup>c</sup> |
|   | Fruit (50% ethanolic) | T6        | 1.98±1.0          | 1.91±0.7           | 1.82±0.9            | 1.69±0.4           | 1.58±0.3          | 1.43±0.7          | 1.42±0.8          | 1.69 <sup>c</sup> |
|   | Leaf (aqueous)        | T7        | 2.84±0.1          | 2.77±0.9           | 2.69±0.2            | 2.49±0.9           | 2.41±0.5          | 2.28±0.8          | 2.21±0.1          | 2.53 <sup>b</sup> |
|   | Leaf (50% ethanolic)  | T8        | 2.72±0.3          | 2.63±0.2           | 2.60±0.7            | 2.42±0.5           | 2.39±0.4          | 2.21±0.7          | 2.17±0.5          | 2.44 <sup>b</sup> |
| Mean  |                       |           | 2.40              | 2.33               | 2.25                | 2.11               | 2.03              | 1.91              | 1.84              |                   |
| Inoculated (without spray)                      |                       | C1        | 3.12±1.4          | 3.26±0.3           | 3.44±0.8            | 3.73±0.5           | 3.85±0.3          | 4.09±0.6          | 4.18±0.6          | 3.67 <sup>a</sup> |
| Uninoculated (water spray)                      |                       | C2        | 1.08±0.3          | 1.01±0.4           | 1.11±0.5            | 1.05±0.7           | 0.97±0.5          | 1.02±0.5          | 1.01±0.5          | 1.04 <sup>d</sup> |
| Overall Mean                                    |                       |           | 2.26 <sup>a</sup> | 2.21 <sup>ab</sup> | 2.15 <sup>abc</sup> | 2.09 <sup>bc</sup> | 2.03 <sup>c</sup> | 1.96 <sup>d</sup> | 1.91 <sup>d</sup> |                   |

Mean±SD, each value with different letter is significantly different ( $p \leq 0.05$ ) as per Tukey's post hoc test; DAT refers to days after treatment

554

555

556

557

558

559

560

561

562 **Table 5.** Effect of foliar spray of promising botanical extracts on peroxidase activity of barley.

| Peroxidase ( $\mu\text{mole min}^{-1} \text{mg}^{-1} \text{protein}^{-1}$ ) |                       |           |                   |                    |                     |                     |                     |                     |                   |                     |
|---|-----------------------|-----------|-------------------|--------------------|---------------------|---------------------|---------------------|---------------------|-------------------|---------------------|
| Tree species  | Spray                 | Treatment | 1 DAT             | 2 DAT              | 3 DAT               | 4 DAT               | 5 DAT               | 6 DAT               | 7 DAT             | MEAN                |
| <i>T. chebulu</i>   | Fruit (aqueous)       | T1        | 1.41±0.3          | 1.52±0.5           | 1.59±0.3            | 1.64±0.4            | 1.71±0.2            | 1.75±0.1            | 1.76±0.2          | 1.62 <sup>ab</sup>  |
|   | Fruit (50% ethanolic) | T2        | 1.53±0.3          | 1.59±0.6           | 1.65±0.3            | 1.67±0.9            | 1.72±0.2            | 1.79±0.1            | 1.82±0.2          | 1.68 <sup>a</sup>   |
|   | Bark (aqueous)        | T3        | 1.24±0.5          | 1.29±0.3           | 1.31±0.4            | 1.42±1.0            | 1.45±0.2            | 1.51±0.1            | 1.56±0.2          | 1.39 <sup>abc</sup> |
|   | Bark (50% ethanolic)  | T4        | 1.27±0.7          | 1.32±0.3           | 1.37±0.3            | 1.43±0.3            | 1.49±0.2            | 1.55±0.1            | 1.59±0.1          | 1.43 <sup>abc</sup> |
| Mean  |                       |           | 1.36              | 1.47               | 1.48                | 1.54                | 1.59                | 1.65                | 1.68              |                     |
| <i>T. bellerica</i>   | Fruit (aqueous)       | T5        | 1.30±0.6          | 1.36±0.3           | 1.41±0.2            | 1.43±0.4            | 1.48±0.2            | 1.50±0.2            | 1.60±0.1          | 1.44 <sup>abc</sup> |
|   | Fruit (50% ethanolic) | T6        | 1.39±0.6          | 1.44±0.3           | 1.57±0.2            | 1.58±0.3            | 1.66±0.3            | 1.71±0.2            | 1.74±0.4          | 1.58 <sup>ab</sup>  |
|   | Leaf (aqueous)        | T7        | 1.17±0.7          | 1.19±0.5           | 1.21±0.2            | 1.26±0.3            | 1.31±0.5            | 1.33±0.1            | 1.42±0.3          | 1.27 <sup>cd</sup>  |
|   | Leaf (50% ethanolic)  | T8        | 1.21±0.7          | 1.24±0.3           | 1.31±0.2            | 1.36±0.4            | 1.44±0.2            | 1.50±0.1            | 1.53±0.3          | 1.36 <sup>bc</sup>  |
| Mean  |                       |           | 1.27              | 1.31               | 1.37                | 1.41                | 1.50                | 1.51                | 1.57              |                     |
| Inoculated (without spray)  |                       | C1        | 0.89±0.1          | 1.27±0.4           | 0.52±0.1            | 0.41±0.3            | 0.23±0.1            | 0.08±0.4            | 0.03±0.2          | 0.50 <sup>e</sup>   |
| Uninoculated (water spray)  |                       | C2        | 1.11±0.1          | 1.03±0.3           | 1.09±0.3            | 1.05±0.3            | 1.10±0.1            | 1.01±0.2            | 1.05±0.8          | 1.06 <sup>d</sup>   |
| Overall Mean  |                       |           | 1.25 <sup>d</sup> | 1.32 <sup>cd</sup> | 1.30 <sup>bcd</sup> | 1.33 <sup>bcd</sup> | 1.36 <sup>bcd</sup> | 1.37 <sup>bcd</sup> | 1.41 <sup>a</sup> |                     |

Mean±SD, each value with different letter is significantly different ( $p \leq 0.05$ ) as per Tukey's post hoc test; DAT refers to days after treatment.

563  
564 **Table 6.** Effect of foliar spray of botanical extracts on phenylalanine ammonia lyase activity  
565 of barley leaves.

| Phenylalanine Ammonia Lyase ( $\mu\text{g min}^{-1} \text{mg}^{-1} \text{protein}^{-1}$ ) |                       |           |                   |                   |                    |                     |                    |                   |                   |                   |
|---|-----------------------|-----------|-------------------|-------------------|--------------------|---------------------|--------------------|-------------------|-------------------|-------------------|
| Tree species  | Spray                 | Treatment | 1 DAT             | 2 DAT             | 3 DAT              | 4 DAT               | 5 DAT              | 6 DAT             | 7 DAT             | MEAN              |
| <i>T. chebulu</i>   | Fruit (aqueous)       | T1        | 4.53±0.2          | 4.58±0.01         | 5.02±0.01          | 5.12±0.01           | 5.13±0.01          | 5.18±0.01         | 5.25±0.01         | 4.97 <sup>b</sup> |
|   | Fruit (50% ethanolic) | T2        | 5.00±0.02         | 5.07±0.03         | 6.18±0.03          | 6.24±0.01           | 6.33±0.01          | 6.63±0.03         | 6.87±0.01         | 6.05 <sup>a</sup> |
|   | Bark (aqueous)        | T3        | 3.86±0.02         | 3.94±0.05         | 4.01±0.04          | 4.04±0.02           | 4.11±0.10          | 4.16±0.01         | 4.20±0.01         | 4.05 <sup>c</sup> |
|   | Bark (50% ethanolic)  | T4        | 3.95±0.01         | 4.01±0.15         | 4.04±0.01          | 4.13±0.02           | 4.18±0.02          | 4.22±0.01         | 4.35±0.02         | 4.13 <sup>c</sup> |
| Mean  |                       |           | 4.33              | 4.4               | 4.81               | 4.89                | 4.94               | 5.04              | 5.17              |                   |
| <i>T. bellerica</i>   | Fruit (aqueous)       | T5        | 4.36±0.02         | 4.41±0.03         | 4.54±0.02          | 4.64±0.03           | 4.87±0.01          | 4.97±0.01         | 4.69±0.25         | 4.69 <sup>b</sup> |
|   | Fruit (50% ethanolic) | T6        | 4.57±0.01         | 4.58±0.02         | 4.88±0.01          | 4.99±0.01           | 5.09±0.04          | 5.14±0.01         | 5.24±0.02         | 4.93 <sup>b</sup> |
|   | Leaf (aqueous)        | T7        | 3.67±0.02         | 3.71±0.02         | 3.77±0.03          | 3.87±0.01           | 3.92±0.02          | 3.98±0.01         | 4.42±0.02         | 3.90 <sup>c</sup> |
|   | Leaf (50% ethanolic)  | T8        | 3.53±0.02         | 3.59±0.04         | 3.97±0.03          | 4.02±0.01           | 4.07±0.01          | 4.13±0.01         | 4.21±0.02         | 3.93 <sup>c</sup> |
| Mean  |                       |           | 4.03              | 4.07              | 4.29               | 4.38                | 4.49               | 4.54              | 4.64              |                   |
| Inoculated (without spray)  |                       | C1        | 1.96±0.12         | 2.54±0.14         | 2.06±0.35          | 1.68±0.54           | 1.32±0.36          | 1.19±0.49         | 1.08±0.46         | 1.69 <sup>e</sup> |
| Uninoculated (water spray)  |                       | C2        | 2.09±0.06         | 2.15±0.09         | 2.10±0.38          | 2.07±0.41           | 2.08±0.52          | 2.11±0.47         | 2.06±0.47         | 2.10 <sup>d</sup> |
| Overall Mean  |                       |           | 3.76 <sup>d</sup> | 3.86 <sup>d</sup> | 4.05 <sup>cd</sup> | 4.08 <sup>bcd</sup> | 4.11 <sup>bc</sup> | 4.17 <sup>b</sup> | 4.23 <sup>a</sup> | 4.04              |

Mean±SD, each value with different letter is significantly different ( $p \leq 0.05$ ) as per Tukey's post hoc test; DAT refers to days after treatment

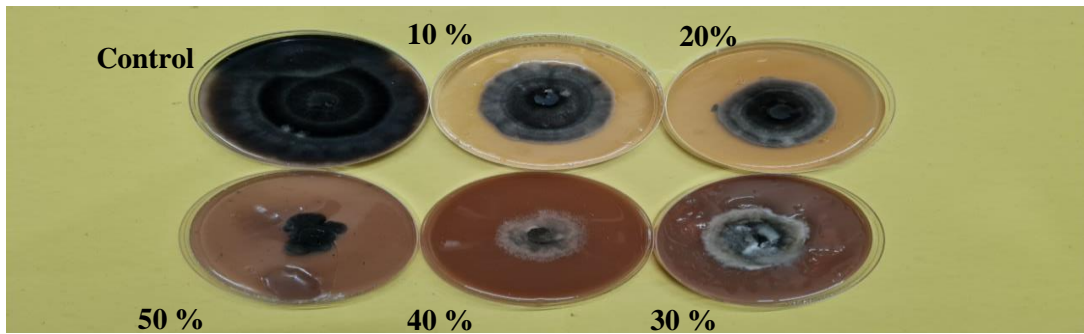
566  
567  
568  
569

570 **Table 7.** Effect of spray of selected botanical extracts on disease and yield parameters in barley.

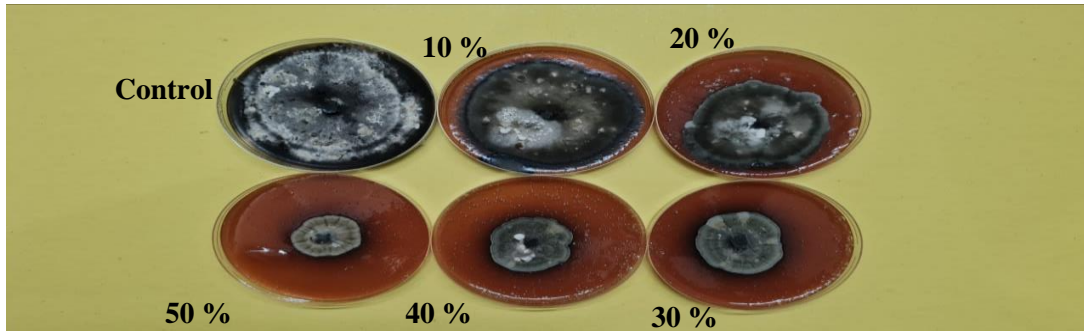
| Spray  | Treatment | Dose  | Terminal Disease severity (%) | Per cent disease control | Yield (q/ac)        | Per cent increase in yield |
|--|-----------|-------|-------------------------------|--------------------------|---------------------|----------------------------|
| <i>T. chebula</i> fruit extract (aqueous)              | T1        | @ 50% | 34.3 <sup>g</sup>             | 63.6 <sup>c</sup>        | 12.8 <sup>bc</sup>  | 36.2 <sup>bc</sup>         |
| <i>T. chebula</i> fruit extract (ethanolic)            | T2        | @ 50% | 29.9 <sup>h</sup>             | 71.1 <sup>b</sup>        | 13.9 <sup>ab</sup>  | 42.4 <sup>ab</sup>         |
| <i>T. chebula</i> bark extract (aqueous)               | T3        | @ 50% | 45.2 <sup>d</sup>             | 44.6 <sup>g</sup>        | 11.4 <sup>bcd</sup> | 20.7 <sup>def</sup>        |
| <i>T. chebula</i> bark extract (ethanolic)             | T4        | @ 50% | 43.6 <sup>e</sup>             | 47.8 <sup>f</sup>        | 11.7 <sup>bcd</sup> | 25.0 <sup>de</sup>         |
| <i>T. bellerica</i> fruit extract (aqueous)            | T5        | @ 50% | 41.5 <sup>f</sup>             | 51.7 <sup>e</sup>        | 11.9 <sup>bcd</sup> | 26.6 <sup>de</sup>         |
| <i>T. bellerica</i> fruit extract (ethanolic)          | T6        | @ 50% | 39.0 <sup>g</sup>             | 58.4 <sup>d</sup>        | 12.2 <sup>bc</sup>  | 29.8 <sup>cd</sup>         |
| <i>T. bellerica</i> leaf extract (aqueous)             | T7        | @ 50% | 50.6 <sup>b</sup>             | 31.8 <sup>i</sup>        | 10.2 <sup>cd</sup>  | 14.9 <sup>f</sup>          |
| <i>T. bellerica</i> leaf extract (ethanolic)           | T8        | @ 50% | 48.9 <sup>c</sup>             | 34.7 <sup>h</sup>        | 10.8 <sup>bcd</sup> | 18.6 <sup>ef</sup>         |
| Control (water sprayed with pathogen spore suspension) | C1        | -     | 69.6 <sup>a</sup>             | -                        | 8.41 <sup>d</sup>   | -                          |
| Uninoculated (only water)                              | C2        | -     | 6.69 <sup>i</sup>             | 90.1 <sup>a</sup>        | 15.3 <sup>a</sup>   | 62.2 <sup>a</sup>          |

Each value with different letter is significantly different ( $p \leq 0.05$ ) as per Tukey's post hoc test

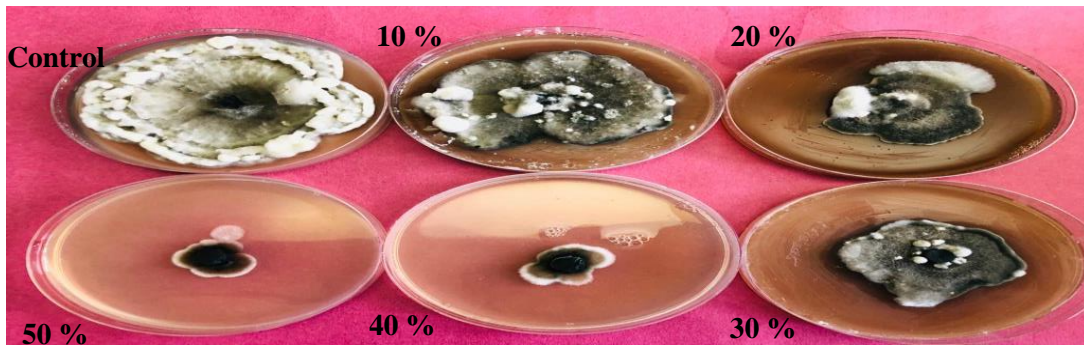
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586



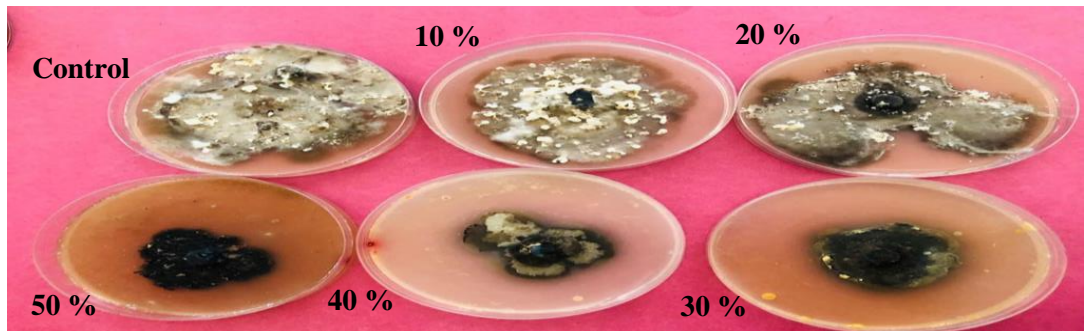
587  
588  
589



590  
591  
592



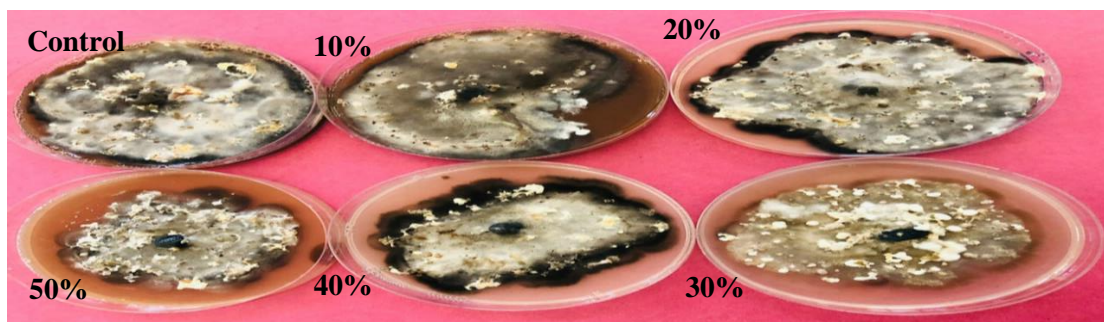
593  
594



595  
596  
597  
598  
599  
600  
601  
602

**Figure 1.** Antifungal activities of fruit extracts of *Terminalia* species against *B. sorokiniana*.

- (A) Fruit ethanolic extract of *T. chebula*
- (B) Fruit ethanolic extract of *T. bellerica*
- (C) Fruit aqueous extract of *T. chebula*
- (D) Fruit aqueous extract of *T. bellerica*



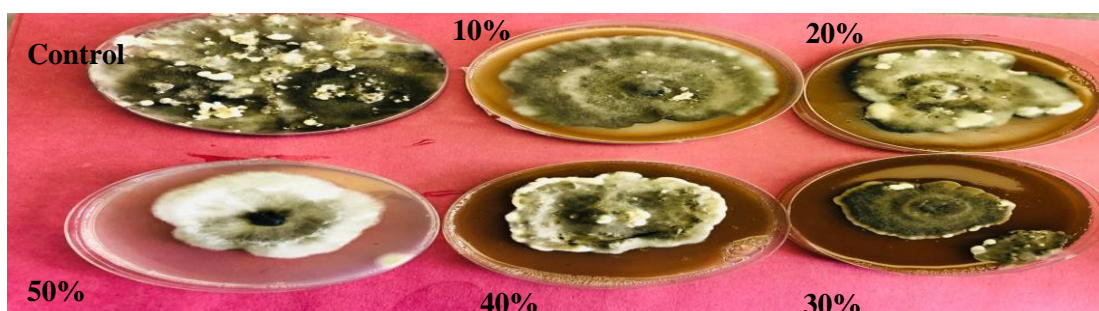
603  
604

(A)



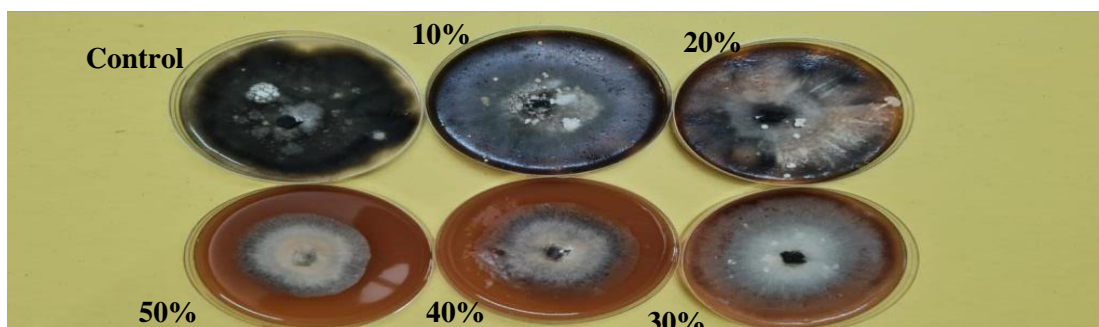
605  
606

(B)



607  
608

(C)



609  
610

(D)

**Figure 2.** Antifungal activities of different extracts of *Terminalia* species against *B. sorokiniana*.

(A) Bark aqueous extract of *T. bellerica*

(B) Bark ethanolic extract of *T. bellerica*

(C) Leaf ethanolic extract of *T. chebula*

(D) Leaf aqueous extract of *T. chebula*

616