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Effect of *Fusarium* wilt disease on varied Chickpea germplasm and its management

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Abstract

Chickpea wilt, caused by *Fusarium oxysporum* f. sp. *ciceris* (Foc) is the most common soil-borne fungus that affects chickpea plants and destroys crops up to 100% in favorable conditions. In the current research, seeds of 12 chickpea varieties were obtained from the Ayub Agricultural Research Institute, Faisalabad (Pakistan). The varieties were sown in augmented design and screened against the *Fusarium* wilt under field conditions. The symptomatic samples were collected and pathogenicity tests performed for the confirmation of pathogen. The food poisoning technique was used to check the effectiveness of 3 fungicides (Capnazole, Flumax and Mixtin) at concentrations (75ppm, 150ppm, 300ppm) *in-vitro* and the most effective concentration was used in field experiments. In management experiment, 3 chickpea varieties (Bittal-110, Noor-2013 and Noor-2019) were sown in a randomized complete block design (RCBD) and a combination of nutrients and chemicals viz; T_1 ($ZnSO_4$+ $MnSO_4$+Boric acid+ Capnazole), T_2 ($ZnSO_4$+ $MnSO_4$+Boric acid+ Flumax), and T_3 (ZnSO4+ $MnSO_4$+Boric acid+ Mixtin) were used by foliar spray methods. The data of environmental variables was collected from the weather observatory and correlated with disease. The results revealed that minimum disease incidence (15.33%) was recorded on AD-08 and maximum disease incidence (68.33%) was recorded on NF1-1733. The maximum mycelial growth inhibition of Foc was recorded at concentration 300 ppm in all 3 fungicides while Capnazole was the most effective with 65.68% inhibition followed by Flumax (60.48%) and Mixtin (36.89%). Under field conditions, T_1 (ZS+MS+BA+Capnazole) was the most effective in controlling wilt disease (33.22%) followed by T_2 (ZS+MS+BA+Flumax), and T_3 (ZS+MS+BA+Mixtin). There was a significantly positive correlation between maximum temperature, minimum temperature, wind speed, rainfall and the negative correlation between relative humidity for disease incidence in present study. The study would provide a base for the sustainable management of wilt disease of chickpea under various agro climatic zones.

Keywords: Capnazole, Chickpea, Environmental factors, *Fusarium* wilt, Micro-nutrients, Screening lines

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Introduction

Grain legumes are known as the poor man's meat that are full of essential nutrients such as protein, phosphorus, iron, calcium, and a lot of other minerals (Cakir et al., 2019; Merga & Haji, 2019). Legumes also have a vital role in nitrogen fixation and are commonly planted in rotation with cereals (Lake & Sadras, 2014; Khan et al., 2020). They have a variety of roles in agro-ecosystems, thus research on legumes would have a huge impact on sustainable development goals like food security and economic stability (Khaitov et al., 2016; Tanaka & Hashimoto, 2019). Chickpea (*Cicer arietinum* L.) is a legume grain crop that has a major competitive role among crop plants. It is high in calories, fiber, protein, vitamins, and minerals as well as phytochemicals that may be beneficial for the body (Gaur et al., 2015; Kaur & Prasad, 2021). Chickpea is a popular staple crop cultivated and consumed throughout the world, mainly in Afro-Asian regions (Devasirvatham & Tan, 2018). Legumes are grown on an area of 1.5 million hectares in Pakistan and produce 0.7 million tonnes of pulses, but the total demand (consumption) is around 1.5 million tonnes. Pakistan must import 0.8 million tonnes of pulses per year to meet the demand from major pulses growing countries of the world (Ullah et al., 2020). Chickpea is a key winter pulse crop among pulses that takes up 73% of the entire area under pulses and produces 76% of the overall yield. The limitations of crop improvement and seed distribution channels, along with pathogenic fungal diseases, are the main reasons for the low chickpea production in Pakistan (Khanna et al., 2022). *Fusarium* wilt is the most dangerous fungal disease that affects the chickpea plant (Zhou et al., 2021). This disease has also been reported in several gram-producing countries, especially in Pakistan. Chickpea wilt is caused by *Fusarium oxysporum* f. sp. *ciceris* (Foc). It can be found in the soil, seeds, and decaying plant materials such as chlamydospore (Fatima et al., 2022). The pathogen, on the other hand, can exist for 2 to 6 years without a host (Mahmood et al., 2015; Jamil & Ashraf, 2020). *Fusarium* blocks the vascular bundle of the affected plant and thus restricts the movement of nutrients and water through xylem vessels (Tian et al., 2022). This fungus has a wider host range and affects many cereals, vegetables, and fruit crops worldwide (Soleha et al., 2022). Crop failures due to this pathogen ranging from 70% to 100% have been reported. *Fusarium* wilt disease is characterized by yellow-colored leaves, discolored vascular bundles, and leaf shedding. In susceptible cultivars, symptoms begin around 25 days after sowing. Root rot signs are similar to wilt disease symptoms, and if not inspected properly, they might be perplexing. The leaves are yellowish and have fallen from a wilting plant to the ground (Anusha et al., 2019). The stem of the plant is thinning, and the base is unhealthy and rotted. The interior tissues of the root turn brown or black when the root is split vertically. This is the first evidence of wilt infection, as the plant has died (Younesi et al., 2021).

In the future, due to the increasing population of the world, the demand for chickpea will be increased. We need to develop hybrid varieties that produce more yield and resistant varieties against this fungal pathogen. Control of this pathogen is very important for better yield production. Therefore, it’s a dire need to control this pathogen by investigating different methods. A few studies have been reported to manage this fungal pathogen by using different chemicals separately and in combination (Prasad & Kumar, 2017; Yadav et al., 2018; Bekele et al., 2021). The nutrients and fungicides would be an effective management strategy along with resistant sources against *Fusarium* wilt of chickpea. Keeping in view the importance of the crop and the destruction caused by Foc, the present study was planned to screen 12 chickpea varieties against wilt disease and *in-vitro* and in-vivo management of this pathogen was done by using a combination of chemicals and micro-nutrients.

Materials and Methods

Screening of chickpea germplasm against *Fusarium* wilt disease

The confirm pure pathogenic isolate of *Fusarium* wilt (*F. oxysporum* f.sp. *ciceris*) was collected from the mycology laboratory Department of Plant Pathology, University of Agriculture Faisalabad (UAF), Faisalabad (Pakistan). The suspension of Foc was prepared for the seed treatment of 12 chickpea varieties which were sown in augmented design. The suspension was made by the serial dilution of 10^3 and seeds were soaked by continuously shaking in an incubator shaker overnight at 25°C and 150rmp. The chickpea varieties; Bittal-110, Noor-2013, Noor-2019, NF1-17339, NF_1-17336, NF_1-17333, NF_1-17342, NF_1-17367, NF_1-17329, NF_1-17345, AD-4 and AD-8 were collected from the Pulses Research Institute (PRI), Ayub Agricultural Research Institute (AARI), Faisalabad (Pakistan).

The symptomatic stem and roots of chickpea infected plants from the experimental area were observed and collected for the confirmation of *Fusarium* wilt. All the collected samples were brought to the Department of Plant Pathology mycology laboratory in UAF for isolation and identification. Potato Dextrose Agar (PDA) media was used for the isolation of associated fungal pathogens and incubated at 25°C for 12 days and microscopically identification was done after colony appearance. Furthermore, the samples were stored in refrigerator at 4°C. The gram varieties were evaluated against wilt disease by recording disease incidence formula in symptomatic plants:

Disease incidence (%) = Number of infected plants/Total number of plants ×100

The screened chickpea germplasm was categorized by the disease rating scale (Table 1) (Iqbal, 2005; Nazir et al., 2012).

Table 1 Disease rating scale against *Fusarium* wilt of chickpea

Scale	Disease incidence %	Response
1	1-10%	Highly resistant
3	11-20%	Resistant
5	21-30%	Moderately resistant
7	31-50%	Susceptible
9	> 50%	Highly susceptible

In-vitro management of Foc with fungicides

In-vitro management of Foc was done with 3 fungicides i.e., Capnazole (Captan+Hexaconazole), Flumax (Fluconazole) and Mixtin by using food poisoning technique in 3 concentrations i.e. 75 ppm, 150 ppm and 300 ppm (Table 2). A stock solution of each fungicide mixed with autoclaved media, poured in a 90 mm sterile petri plate and 03 plates of each treatment were made. A 5 mm disk of pure 12 days old *Fusarium* colony was added in the center of PDA solidified plates and incubated at 25 °C. The data on radial mycelial growth (mm) of *Fusarium* were recorded after 3, 5 and 7 days of incubation (Fig. 1).

Table 2 Complete details of treatments applied against *Fusarium* wilt of chickpea

Sr. No.	Treatments (Concentration)	Abbreviations
T1	$ZnSO_4$+ $MnSO_4$+Boric acid+ Capnazole (1 g/L)	ZnS+MnS+BA+CZ
T2	$ZnSO_4$+ $MnSO_4$+Boric acid+Flumax (0.5 ml/L)	ZnS+MnS+BA+FM
T3	ZnSO4+ $MnSO_4$+Boric acid+ Mixtin (0.5 ml/L)	ZnS+MnS+BA+MT

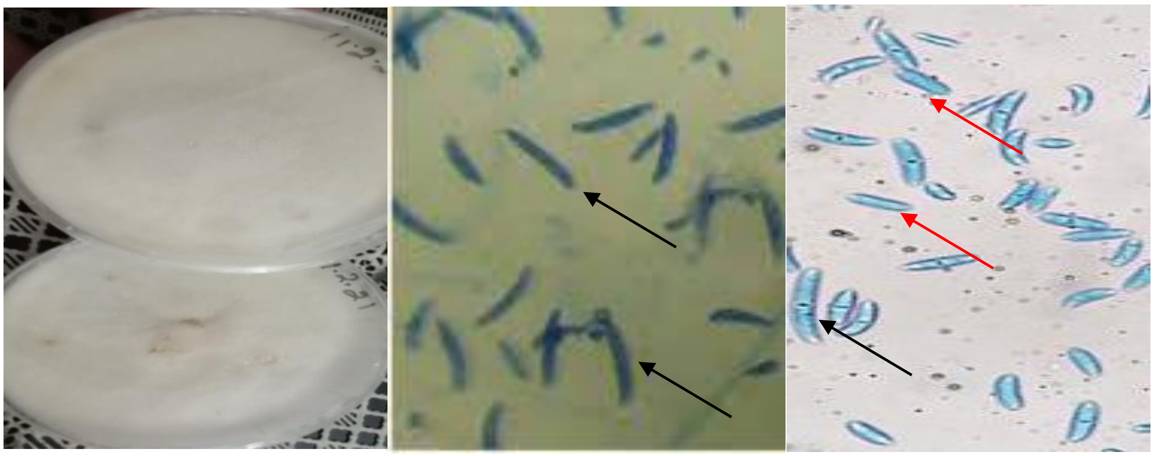

Fig. 1 Pure culture of *F. oxysporum* f. sp.*Ciceris*and black arrow indicated the Macro-conidia and red arrow indicated the Micro-conidia of *F. oxysporum* f. sp.*Ciceris.*

Management of *Fusarium* wilt through fungicides and nutrients

The chickpea seeds (Bittal-110, Noor-2013 and Noor-2019) were sown in the experimental area of Department of Plant Pathology, UAF by using randomized complete block (RCBD) design with 3 replications in management trail. The most effective concentration (300 ppm) of all 3 fungicides found from *in-vitro* trials was used along with nutrients in field trials. Three treatments i.e. nutrients + chemicals and one control experiment were used to manage the chickpea wilt and all standard agronomic practices were performed. The treatments were applied by foliar spray where nutrients (Boric acid, Manganese sulphate and Zinc sulphate) and fungicides (Capnazole, Flumax and Mixtin) were used. The disease incidence data was recorded by the above mentioned formula on a weekly basis to check the effectiveness of treatments.

Characterizations of environmental variables for the development of chickpea wilt disease

The data of maximum and minimum temperature, wind speed, relative humidity and rainfall was collected from the website of UAF (www.uaf.edu.pk). The influence of each variable (maximum and minimum temperature, relative humidity, rainfall and wind speed) on disease development was determined by simple correlation and regression analysis.

Statistical analysis

Statistical analysis was done to determine significance by using statistics 8.1. The information gathered throughout the evaluation process was evaluated and represented in tables and graphs. ANOVA (analysis of variance) results have been provided for a variety of factors. The treatment effects have been presented in terms of statistical interpretation and comparison between disease severity and environmental conditions were made through least significant difference test (LSD at P<0.05). Effects of environmental parameters (maximum and minimum temperatures, relative humidity, rainfall and wind speed) on disease severity were determined by correlation analysis (Steel et al., 1997).

Results

Response of chickpea germplasms against *Fusarium* wilt disease under field conditions

Three chickpea cultivars were resistant to disease viz. AD-08 (15.33%), NF1-17367 (15.67%) and NF1-17329(17.67%). The moderately resistant genotypes were Noor-2019(23%), NF1-17342 (24.33%), AD-04 (25.33%) and NF1-17345 (26.33%). The susceptible genotypes were Bittal-110 (38.33%), NF1-17339 (38.33%) and Noor-2013 (43.33%). While the highly susceptible genotypes NF1-17336 (61.33%) and NF1-17333

(68.33%) for *Fusarium* wilt of chickpea were recorded (Table 3; Fig. 2).

Table 3 Response of different varieties/lines of chickpea against the disease

Scales	Disease categories	Varieties	Disease incidence (%)	Response
1	0 %	–	–	Immune
2	1-10 %	–	–	Highly resistant
3	11-20 %	AD-08 NF1-17367 NF1-17329	15.33 15.67 17.67	Resistant
4	21-30 %	Noor-2019 NF1-17342 AD-04 NF1-17345	23.00 24.33 25.33 26.33	Moderately resistant
5	31-50 %	Bittal-110 NF1-17339 Noor-2013	38.33 38.33 43.33	Susceptible
6	>50 %	NF1-17336 NF1-17333	61.33 68.33	Highly susceptible

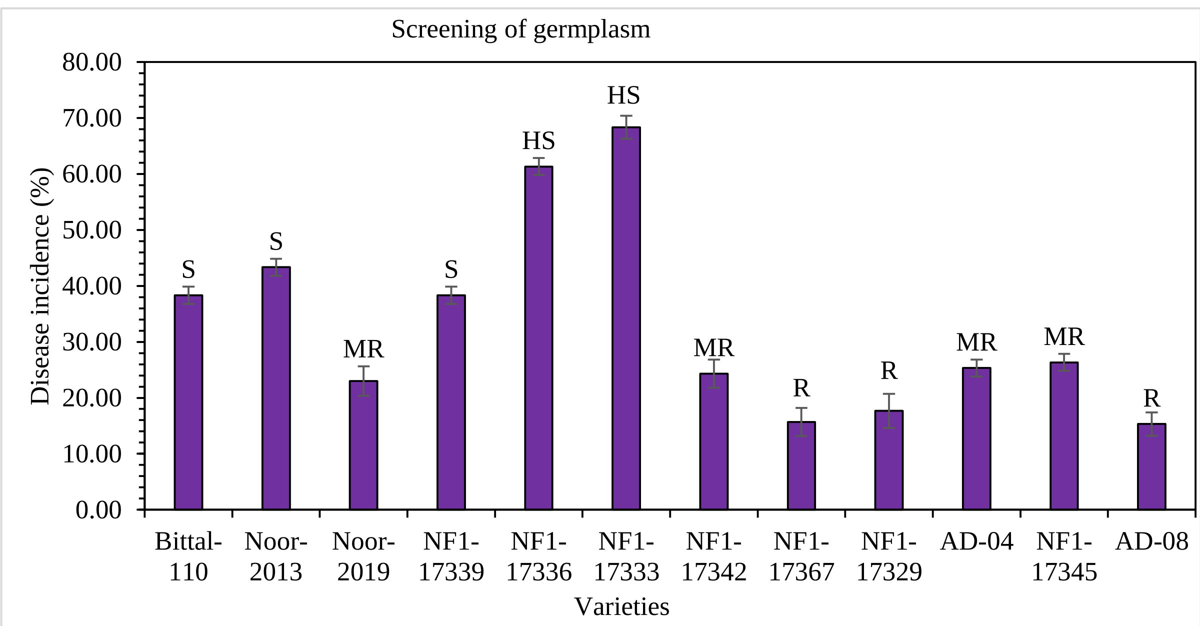

Fig. 2 Graphical representation of disease incidence on chickpea germplasm against *Fusarium* wilt under natural conditions

In vitro managements of *F. oxysporum* f. sp. *ciceris*

In-vitro management of *F. oxysporum* f. sp. *ciceris* was done with 3 well-known fungicides named Capnazole, Flumaxand Mixtin with 75 ppm, 150 ppm and 300 ppm concentrations through food poisoning technique. The results revealed that the fungicide Capnazole at all concentration performed good in inhibition of mycelial growth of Foc. Flumax and Mixtin also performed well after Capnazole by inhibiting the targeted fungal growth. At 75ppm on 3rd 5th and 7th day Capnazole (50.40%, 62.36% and 66.23%), Flumax (41.56%, 58.03% and 59.23%) and Mixtin (17.70%, 25.16% and 27.23%) inhibited the mycelial growth respectively. At 150 ppm on 3rd, 5th and 7th day Capnazole (69.00%, 72.63% and 79.06%), Flumax (53.83%, 58.20% and 60.56%) and Mixtin (34.46%, 35.56% and 38.36%) inhibited the mycelial growth. At 300 ppm on 3rd, 5th and 7th day Capnazole (74.53%, 75.16% and 80.73%), Flumax (66.40%, 70.66% and 75.90%) and Mixtin (42.36%, 55.23% and 55%) inhibited the mycelial growth.Interaction effect for treatments and concentrations showed that the maximum growth inhibition and minimum growth inhibition was recorded (Table 4; Fig. 3).

The average inhibition of mycelial growth of Foc at 75ppm is more significant for Capnazole (59.66%) followed by Flumax (52.94%) and Mixtin (23.36%). The maximum average mycelial growth inhibition at 150ppm was recorded for Capnazole (60.6%) followed by Flumax (57.53%) and Mixtin (36.12%). At 300ppm, maximum mycelial growth inhibition was recorded by Capnazole (76.8%) followed by Flumax (70.98%) and Mixtin (51.19%). The average of the control plate is 100% at all stages. The average of all three concentrations were recorded for Capnazole (65.68%) as compared to Flumax (60.48%) and Mixtin (36.89%). Finally concluded that the Capnazole inhibits the maximum mycelial growth of Foc at all concentrations followed by Flumax and Mixtin.

Table 4 All-pair wise comparisons of fungicide percent growth inhibition (%) after 3rd, 5th and 7th days

Concen-trations	Capnazole (Days %)			Flumax (Days %)			Mixtin (Days %)		
	3	5	7	3	5	7	3	5	7
75ppm	50.40 cd	62.36 b	66.23 b	41.56 d	58.03 c	59.23 c	17.70 e	25.16 e	27.23 e
150ppm	69.00 a	72.63 a	79.06 a	53.83 c	58.20 c	60.56 b	34.46 d	35.56 d	38.36 d
300ppm	74.53 a	75.16 a	80.73 a	66.40 a	70.66 ab	75.90 b	42.36 d	55.23 c	56.00 c

*The means with different letters in a column are significantly different from each other at 5% probability level

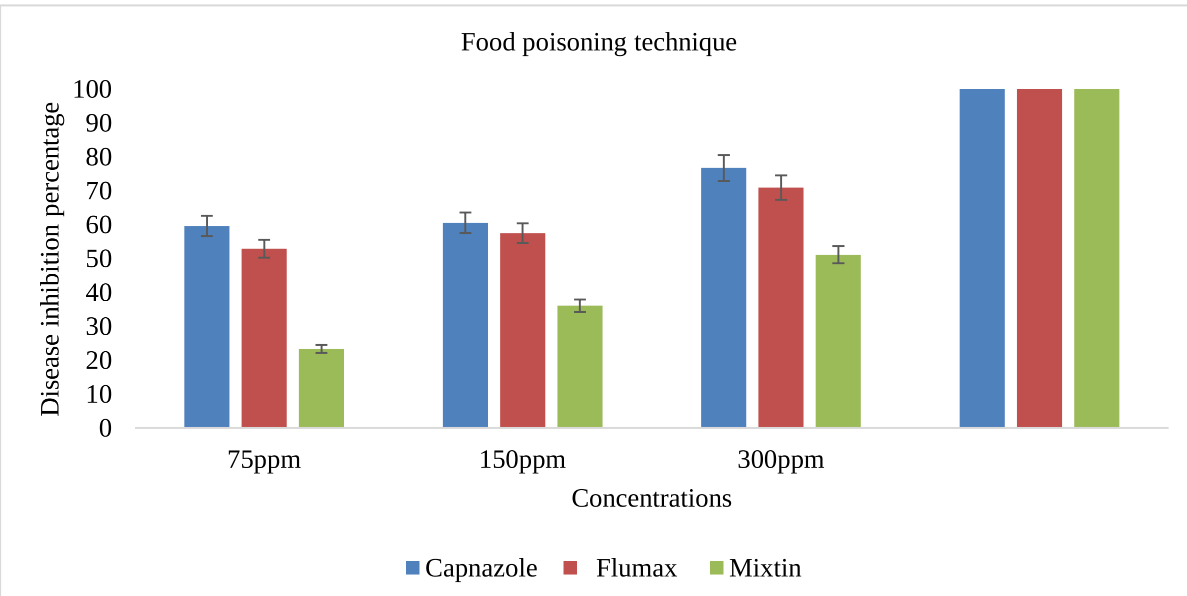

Fig. 3 *In vitro* mycelial inhibition of *F. oxysporum* f. sp.*Ciceris* by applied fungicides

In-vivo management of *F. oxysporum* f. sp. *ciceris*

The data regarding the effectiveness of various chemicals/treatments against *Fusarium* wilt on chickpea revealed that all treatments showed significant results in controlling/reducing the disease incidence. The treatment T_1 (ZnS+MnS+BA+CZ) showed overall best results and showed less disease incidence as compared to control (Table 5). Similarly, T_2 (ZnS+MnS+BA+FM) showed also good results after T_1 while T_3 (ZnS+MnS+BA+MT) showed minimal results in reducing the disease incidence as compared to T_1 and T_2 and control (Table 5). The comparison of 2-way interaction of varieties and treatments showed that Noor 2019 performed best against disease incidence in all dates of observation. Likewise, the variety Bital-110 also performed well in controlling disease after Noor-2019. While our variety Noor-2013 showed less/minimum result in suppressing/minimizing the disease incidence as compared to Noor-2019 and Bital-110 (Table 6).

Table 5 Percent (%) disease incidence recorded for treatments

Treatment	Percent (%) disease incidence for treatments (Date)			
	03-03-2021	15-02-2021	19-03-2021	04-04-2021
Control	75.44^{a}	60.67^{a}	80.00^{a}	94.44^{a}
ZS+MS+BA+Capnozol	64.56^{a}	42.11^{b}	38.00^{c}	33.22^{d}
ZS+MS+BA+Flumax	68.11^{a}	53.78^{b}	47.05^{c}	41.78^{d}

ZS+MS+BA+Mixtin	70.22[a]	56.22[b]	51.56[c]	47.67[d]

*The means with different letters in a row are significantly different from each other at 5% probability level

Table 6 Percent (%) disease incidence recorded for varieties

Varieties	Percent (%) disease incidence for varieties (Date)			
	15-02-2021	03-03-2021	19-03-2021	04-04-2021
Bittal-110	62.67[b]	57.08[b]	58.00[b]	67.50[b]
Noor-2013	69.08[a]	62.75[a]	64.25[a]	73.42[a]
Noor-2019	56.67[c]	53.67[c]	53.67[c]	60.17[c]

*The means with different letters in a column are significantly different from each other at 5% probability level

Effect of environmental factors on disease development

The correlation of environmental variables i.e. maximum temperature, minimum temperature, wind speed, relative humidity and rainfall with *Fusarium* wilt of chickpea was described in under given (Table 7). There was a highly significant ($p<0.05$) but positive correlation between maximum temperature and disease incidence of all 3 varieties and the values were Noor-2103 (r = 0.80) followed by Bittal-110 (r = 0.85) and Noor-2019 (r = 0.86). The highly significant ($p<0.05$) but positive correlation between minimum temperature and disease incidence of all 3 varieties and the values were Noor-2103 (r = 0.93) followed by Bittal-110 (r = 0.97) and Noor-2013 (r = 0.97). The negative correlation between relative humidity and disease incidence of all the three varieties as the relative humidity increases and the disease incidence decreases. The relationship was found significant at $p<0.05$ for Bittal-110, Noor-2103 and highly significant for Noor-2019. The value of correlation coefficients of the varieties were Noor-2103 (r = - 0.58) followed by Bittal-110 (r = - 0.66) and Noor-2019 (r = - 0.73). There is a highly positive significant correlation between wind speed and disease incidence of all the 3 varieties and the values were Noor-2103 (r = 0.93) followed by Bittal-110 (r = 0.95) and Noor-2013 (r = 0.93). The positive correlation between rainfall and disease incidence of all the 3 varieties and the values were Noor-2109 (r = 0.44) followed by Bittal-110 (r = 0.52) and Noor-2013 (r = 0.59).

Table 7 Correlations of environmental variables with disease incidence

Environmental Variables	Bittal-110	Noor-2013	Noor-2019
Max. Temperature	0.8544	0.8036	0.8578
p-Value	0.0004**	0.0016**	0.0004**
Min. Temperature	0.9667	0.9308	0.9689
p-Value	0.0000**	0.0000**	0.0000**
Wind Speed	0.9482	0.9277	0.9261
p-Value	0.0000**	0.0000**	0.0000**
Relative Humidity	-0.6622	-0.5820	-0.7295
p-Value	0.0190*	0.0471*	0.0071**
Rain Fall	0.5190	0.5868	0.4424
p-Value	0.0838[NS]	0.0449*	0.1498[NS]

** Highly Significant p-value < 0.01; * Significant p-value < 0.05; [NS] Non-significant p-value > 0.05

Discussion

Chickpeas can be eaten raw or processed into a variety of items (Jukanti et al., 2012). Soaking, decortication, parching, roasting, sprouting, frying, steaming, mashing, fermentation, grinding and boiling are some of the traditional chickpea preparation and processing procedures (Roy et al., 2010). Pakistan produces 10% of the world's chickpeas where yield is badly affected by *Fusarium* wilt disease (Zhou et al., 2021). Chickpea wilt is caused by *Fusarium oxysporum* f. sp. *ciceris* (Foc). It can be found in the soil, seeds, and decaying plant materials as chlamydospore and the pathogen can exist for 02 to 06 years without a host (Jamil & Ashraf, 2020; Mahmood et al., 2015). Crop failures due to this pathogen ranging from 70% to 100% have been reported. The screening results revealed that not even a single chickpea line is highly resistant against the *Fusarium* wilt. These results are in line with Husnain et al. (2016) explained the results of tested 64 chickpea germplasm against *Fusarium* wilt and described that 7 lines were highly resistant, 11 resistant and 10 lines were moderately resistant. The other all lines were susceptible and highly susceptible results. However, as compared to this study our study shows no highly resistant line against this virulent fungal pathogen. The results of Chaudhry et al. (2007) study is similar to present research, they used 196 lines of chickpea germplasm against the *Fusarium* wilt pathogen and none of the lines were highly resistant to this pathogen but a few lines are resistant and moderately resistant and all other lines are susceptible and highly susceptible. Khanna et al. (2022) evaluated various chickpea cultivars against wilt disease and checked for host resistance through disease dynamics. None of the cultivar was found highly resistant based upon phenotypic observations. Srivastava et al. (2021) concluded that the chickpea varieties with stable resistance against wilt disease could be incorporated in breeding programs for sustainable management. Ali and Terefe studied the spatial distribution of chickpea wilt disease and found 100% prevalence in 63 selected fields of different geographical regions. Hotkar (2018) found the resistant lines among a wide chickpea germplasm by recording disease incidence and severity according to a defined disease rating scale. Furthermore, similar results were obtained by Zewdie & Bedasa (2018); Mahajan et al. (2019); Zewdie & Bedasa (2020).

In present study, *in-vitro* management results revealed that the fungicide Capnazole 3rd performed best as compared to Flumax and Mixtin at all concentrations. Mengist et al. (2018) used 2 fungicides i.e. mancozeb and Apron Star against Foc *in-vitro*. Apron Star inhibited the maximum mycelial growth of Foc. Capnazole contains fluconazole as an active ingredient that inhibits extracellular hydrolytic enzyme aspartyl proteinase, disrupts biofilm components, disrupts cell membrane and cell wall, release silver ions, damages DNA, destabilizes ribosomes and mitochondria (Zainab et al., 2022). Fatima et al. (2022) found significantly positive fungicidal impact of Score, Topsin M and Bavistin against Foc *in-vitro* and *in-vivo*. Muhammad et al. (2022) evaluated different fungicides along with plant activators under field conditions and described the most efficient disease control in Capnazole treated plots. Hassan et al. (2022) used poison food technique for *in-vitro* evaluation of different fungicides and found maximum mycelial growth inhibition in Flumax treated isolates. In current research Chickpea wilt was managed by the combination of fungicides and nutrients under field conditions. The data revealed that all treatments showed significant results in controlling the disease incidence. Ning et al. (2019) applied foliar sprays of zinc along with certain fungicides and found better yield and less disease incidence as compared to fungicides alone. Noman et al. (2019) stated that Zinc has a significant role in growth, development and protection against diseases as it stabilizes the production of superoxide dismutase. Luo et al. (2020) described that zinc and manganese inhibited mycelial growth, sporangial production and zoospore germination under *in-vitro* conditions. Salim et al. (2019) described the role of boric acid in disease management as it increases the amount of essential micro nutrients carotenoids in plants which in turn regulates the amount of antioxidants under stress conditions. Recently to control the *Fusarium* wilt of chickpea a lot of new fungicides were used and founded the good results by Yadav et al. (2018); Jamil and Ashraf (2020); Ahamad et al. (2020) and Nandeesha and Huilgol (2021).

Similar to present study, a lot of reported research described that the disease incidence of *Fusarium* wilt has been significantly influenced due to environmental factors. The chickpea wilt disease is affected due to the temperature, rainfall, humidity and fluctuation were also explained previously (Ali & Terefe, 2021; Devasirvatham & Tan, 2018). Temperature has a substantial link with *Fusarium* wilt of chickpea, which can be explained by the fact that it plays a key role in various areas of disease progression and symptom expression (Mehmood et al., 2013). Rainfall played a vital influence in the early stages of infection, which starts with the production of fast spores on wet days (Jha et al., 2015). There was significantly positive correlation between disease severity and maximum temperature, minimum temperature and relative humidity (Khanna et al., 2022). Kaur et al. (2021) documented the effect of temperature on wilt of chickpea and concluded that there was minimum disease at low temperature. Farmers can use fungicides during the period when these crucial ranges prevail in the semi-arid zone, which is known as a dangerous period.

Conclusion

The above study shows that all tested Chickpea germplasms failed against the discussed fungal pathogen. However, Noor 2019 is a single germplasm having some moderate resistance against the tested pathogen but not 100%. Therefore, the well-known tested resistance genotypes against a virulent isolate of *F. oxysporum* f. sp*ciceri* exist in the world with higher modification in their genetic makeups.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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