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Occurrence, Pathogenic Variability and Cultivar Response to Fusarium Wilt of Cucumber in High Plastic Tunnels of Balochistan, Pakistan

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ABSTRACT

Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *cucumerinum* (FOC), is an emerging constraint on tunnel-grown cucumber (*Cucumis sativus* L.) in Balochistan, Pakistan. Limited field-level information is available in the literature on its distribution, aggressiveness, and cultivar reaction in this region. A survey of high tunnels across the upland districts of Balochistan, namely Quetta, Pishin and Mastung was conducted in 2022 and 2023. Fusarium wilt was recorded at every location, with incidence ranging from 21.80 to 57.20%; Quetta was the most severely affected. Nine isolates recovered from infected tissue were morphologically identified as *F. oxysporum* associated with cucumber wilt and confirmed pathogenic by soil-infestation pot assays. All nine isolates were pathogenic, with plant mortality ranging from 21.25 to 92.00% and root infection from 32.50 to 98.00%; five isolates (FOC1, FOC2, FOC6, FOC8 and FOC9) were classified as highly pathogenic on the basis of mortality, with FOC2 the most aggressive, causing the highest mortality (92%) and root infection (98%). When five commercial cultivars (Arista, R-Yield, Star One, Subhan and Mawasem) were challenged with FOC2, all were susceptible but differed significantly in degree: Mawasem was most susceptible (95.00% mortality, 96.50% root infection) with the greatest growth suppression, while Arista was comparatively less susceptible (32.25% mortality, 40.00% root infection) with the best growth performance. None of the five evaluated commercial cultivars showed complete resistance to FOC2, although Arista and R-Yield exhibited comparatively lower disease severity and better growth. These findings indicate that Fusarium wilt is an important disease constraint in the surveyed cucumber tunnels of Balochistan, underscoring the need for integrated management and further resistance-breeding work.

KEYWORDS: *Cucumis sativus*, *Fusarium oxysporum*, disease incidence, pathogenic variability, cultivar screening, Balochistan

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a major member of the family *Cucurbitaceae* and one of the most widely grown vegetable crops in the world, occupying about 2.27 million hectares globally with a production of roughly 83.7 million tonnes (Tariq *et al.*, 2020). Pakistan ranks 50th among producing countries. Cucumber is cultivated on approximately 3.20 thousand hectares yielding 123.67 thousand tonnes annually, concentrated mainly in Punjab and Balochistan (Govt. of Pakistan, 2025), and is valued mainly as a fresh salad vegetable and pickling crop, owing in part to its high-water content and contribution of vitamins and antioxidants to the diet (Sotiroudis *et al.*, 2010; Nema *et al.*, 2011; Sharma *et al.*, 2012; Uthpala *et al.*, 2020).

In Balochistan, limited arable land and water scarcity, together with rising market demand, have made high plastic tunnels an increasingly popular production system for cucumber (Kumar *et al.*, 2020). The warm, humid conditions inside tunnels, however, also favour soil-borne diseases, most particularly

Fusarium wilt associated worldwide with *Fusarium oxysporum* f. sp. *cucumerinum* (FOC), transmitted through infested soil and irrigation water (Shen *et al.*, 2008; Wang *et al.*, 2021), and reported to cause yield losses of 40-70% in affected regions worldwide (Sharma and Shukla, 2021). Many growers in Balochistan plant cucumber in the same tunnel soil season after season; such continuous mono-cropping is known to accelerate the build-up of soil-borne inoculum and secondary salinization, shifting the soil fungal community toward pathogenic species such as *Fusarium oxysporum* (Meng *et al.*, 2018; Cheng *et al.*, 2020). Once established, the pathogen colonizes the vascular system, producing yellowing, wilting, stunting and eventually plant death, with severity enhanced by the higher temperature and humidity typical of tunnel microclimates (Agrios, 2005; Leslie and Summerell, 2006; Okungbowa and Shittu, 2012; Dauda *et al.*, 2022).

Although Fusarium wilt of cucumber is well documented in major production regions elsewhere, field-level information on its distribution, the

pathogenic variability of local FOC populations, and the reaction of commercially grown cultivars has not previously been reported for the tunnel-based cucumber industry of Balochistan. Such data are a prerequisite for designing rotation schedules, resistant-cultivar deployment and other locally suited management interventions. The specific objectives of the present study were to (i) determine the incidence of Fusarium wilt in high tunnels across the major cucumber-growing districts of Balochistan, (ii) isolate and morphologically characterize the causal pathogen, (iii) evaluate the comparative aggressiveness of the field isolates recovered, and (iv) screen commercially available cucumber cultivars for their reaction to the most aggressive isolate.

MATERIALS AND METHODS

Survey area and disease-incidence assessment: A field survey was conducted from March to May in 2022 in high plastic tunnels across the three major tunnel-farming districts in the uplands of Balochistan: Quetta (Sariab, Baleli, Akhtar Abad), Pishin (Yaru, Faizabad, Malezai) and Mastung (Dasht, Pringabad, Khadkoocha) (Table 1). At each location, five to ten tunnels were surveyed and 200 randomly selected plants per tunnel were examined for typical wilt symptoms and the same tunnels were resurveyed in 2023. At the time of survey tunnel age, cultivar name, crop age, prior cropping history, irrigation method, and prevailing disease-management practices at each surveyed tunnel were also recorded, as these factors are known to influence development of Fusarium wilt. Disease incidence (%) was calculated as (number of infected plants / total plants observed) $\times$ 100

Table 1. Surveyed districts and locations.

District	Locations surveyed
Quetta	Sariab, Baleli, Akhtar Abad
Pishin	Yaru, Faizabad, Malezai
Mastung	Dasht, Pringabad, Khadkoocha

Sample collection, isolation and morphological characterization: From each tunnel, roots, stems and rhizosphere soil were collected from ten randomly selected symptomatic plants (yellowing, wilting, vascular discoloration), sealed in labelled paper envelopes and transported to the Laboratory of Plant Pathology. Root and stem tissue was cut into 5-mm sections encompassing discoloured xylem, surface-sterilized in 1% sodium hypochlorite for 1 min, rinsed twice in sterile distilled water, and plated on potato dextrose agar (PDA), incubated at 27 °C for 7 days. Emerging mycelium was sub-cultured until pure cultures were obtained and maintained at 4 °C. Colony colour, texture and growth rate were recorded, and the shape and size of microconidia, macroconidia and chlamydospores were examined under a compound microscope, following the identification criteria of Leslie and Summerell (2006).

Pathogenicity confirmation and inoculum preparation: Pathogenicity of each isolate was confirmed by Koch's postulates: the pathogen was re-isolated from inoculated plants reproducing typical wilt symptoms and compared morphologically with the original culture. Conidial suspensions were prepared from 10-day-old PDA cultures by flooding plates with 10 ml sterile distilled water, filtering through muslin

cloth, and adjusting the concentration to 1×10^6 spores ml⁻¹ with a haemocytometer (Vargas-Inciarte *et al.*, 2019).

Aggressiveness assay of the nine isolates: Comparative aggressiveness was assessed by a soil-infestation method in 30-cm earthen pots containing 2 kg of a sterilized sand: compost (2:1, w/w) mixture under greenhouse. Soil in each pot (except the non-inoculated control) was infested with 20 ml of conidial suspension (1×10^6 spores ml⁻¹, equivalent to a total inoculum load of 2×10^7 conidia per pot) mixed into the top 10 cm and left for one week before sowing. This inoculum density follows established soil-infestation protocols for Fusarium wilt pathogenicity assays (Vargas-Inciarte *et al.*, 2019). Seeds of the susceptible cultivar Mawasem were surface-sterilized with 2% sodium hypochlorite for 3 min, rinsed three times in sterile distilled water to remove surface contamination, and sown in pots (Din, 2020). Germination, symptom development, plant mortality and root infection were recorded at the end of the observation period; isolates were then categorized as non-pathogenic, pathogenic, moderately pathogenic or highly pathogenic on the basis of plant mortality and root infection (%) (Table 2).

Table 2. Aggressiveness scale for classifying FOC isolates.

Scale	Mortality (%) – primary criterion	Category
0	0	Non-pathogenic
1	1-25	Pathogenic
2	26-50	Moderately pathogenic
3	51-100	Highly pathogenic

Screening of cucumber cultivars: Five commercial cultivars (Arista, R-Yield, Star One, Subhan,

Mawasem), obtained from the Directorate of Vegetable Seed Production, Agriculture Research Institute,

Quetta, were evaluated against the most aggressive isolate (FOC2) identified in the preceding experiment. Pots were prepared and inoculated as described above. Five surface-sterilized seeds of each cultivar were sown per pot and thinned to one seedling per pot after germination. After one month, plants were uprooted and assessed for plant mortality (PM), root infection (RI), and shoot and root length and fresh weight. PM% and RI% were recorded by the given formula = (number of dead plants or colonized root pieces / total observed) × 100.

Statistical analysis: The field survey was descriptive, and incidence differences among districts/locations were not subjected to formal inferential statistical testing. The pot-based aggressiveness assay and cultivar-screening experiment each followed a completely randomized design (CRD) with four replications. Data from these experiments were

subjected to analysis of variance (ANOVA), and treatment means were separated using the Least Significant Difference (LSD) test at $p < 0.05$, using the Statistix 8.1 software package.

RESULTS

Field symptoms and disease incidence: Typical Fusarium wilt symptoms were observed at every surveyed location in both seedlings and mature plants, most noticeable in humid tunnels around the fruiting stage: affected seedlings showed light-green to yellow foliage followed by wilting and necrosis, while older plants showed progressive lower-leaf yellowing, drooping, wilting and death, and the roots showed vascular browning and discoloration when cut longitudinally (Figure 1).

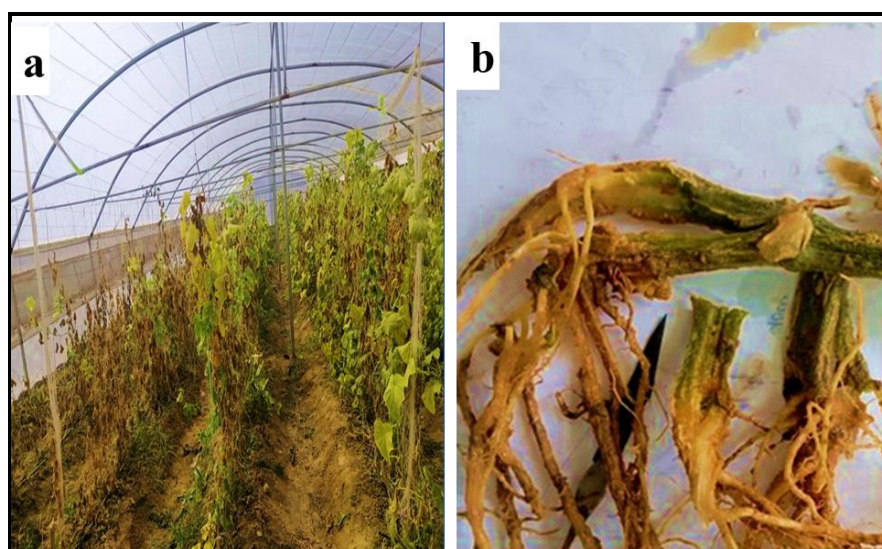


Figure 1. (a) Fusarium wilt symptoms in a high plastic tunnel; (b) vascular discoloration of infected roots and stems.

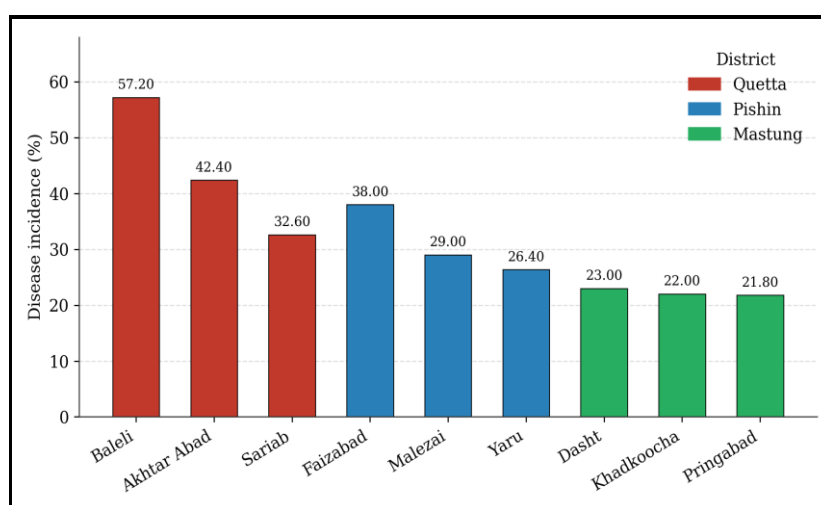


Figure 2. Incidence (%) of Fusarium wilt of cucumber in high plastic tunnels across three districts of Balochistan.

Fusarium wilt was recorded at every location, with incidence ranging from 21.80 to 57.20% (Figure 2).

Quetta was most severely affected (Baleli 57.20%, Akhtar Abad 42.40%, Sariat 32.60%), followed by

Pishin (Faizabad 38.00%, Malezai 29.00%, Yaru 26.40%) and Mastung (Dasht 23.00%, Khadkoocha 22.00%, Pringabad 21.80%); overall disease pressure followed Quetta > Pishin > Mastung.

Isolation and morphological characterization: A single dominant fungal species was consistently recovered from symptomatic tissue across every sample. Nine isolates (FOC1-FOC9) produced whitish aerial mycelium on PDA that turned pinkish to purple with age, filling a 90-mm plate within 6-7 days. FOC2

grew fastest and developed pigmentation slightly earlier than the other isolates (Figure 3). Macroconidia were multicelled, elongated and sickle-shaped ($25-55 \times 3-5$ microns, 3-5 septa); microconidia were single- or two-celled, oval to kidney-shaped and aseptate; chlamydospores were spherical, occurring singly, in pairs or in chains (Figure 4). All nine isolates were morphologically consistent with *F. oxysporum*, following the description of Leslie and Summerell (2006) and the approach used by Din et al. (2020).

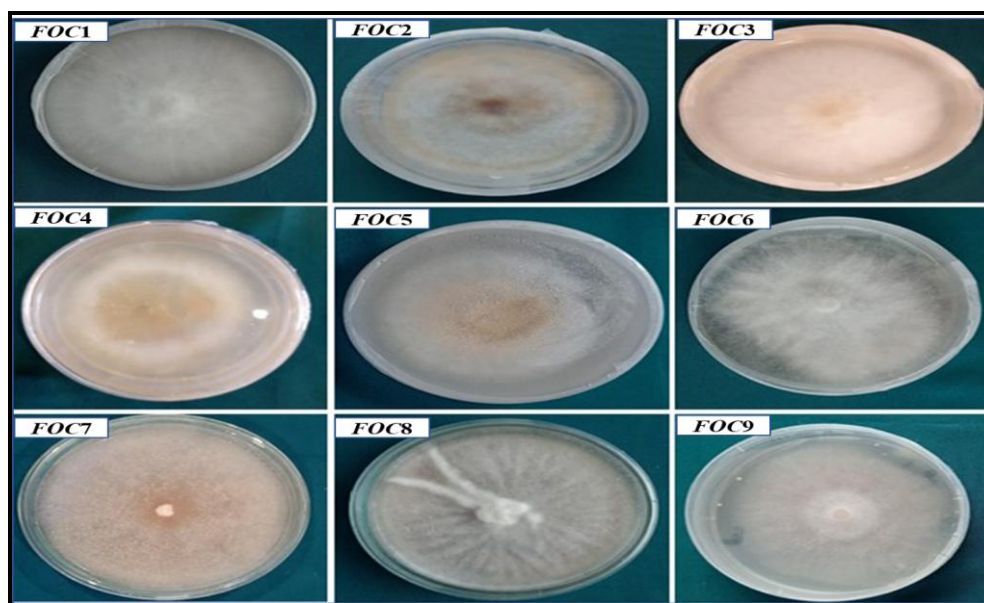


Figure 3. Pure cultures of the nine FOC isolates on potato dextrose agar.

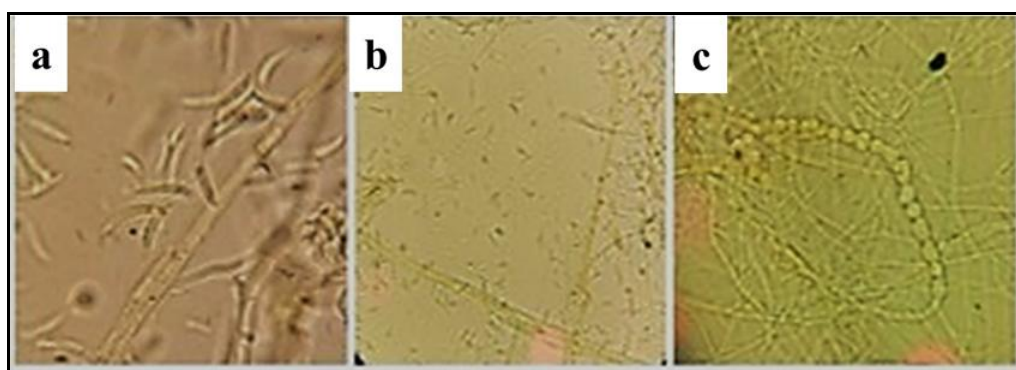


Figure 4. Photomicrographs of FOC: (a) macroconidia, (b) microconidia, (c) chlamydospores.

Aggressiveness of the nine FOC isolates: All nine isolates were pathogenic, producing typical wilting, yellowing and stunting, whereas non-inoculated control plants remained completely symptom-free (0.00% mortality, 0.00% root infection). Plant mortality ranged from 21.25 to 92.00% and root infection from 32.50 to 98.00%. Using the scale in Table 2, isolates FOC1, FOC2, FOC6, FOC8 and

FOC9 were highly pathogenic (63.75-92.00% mortality, 65.75-98.00% root infection), with FOC2 clearly being the most aggressive (92.00% mortality, 98.00% root infection). FOC3 and FOC7 were moderately pathogenic (31.25 and 49.25% mortality), while FOC4 and FOC5 were the least aggressive, classified as pathogenic (25.00 and 21.25% mortality) (Figure 5).

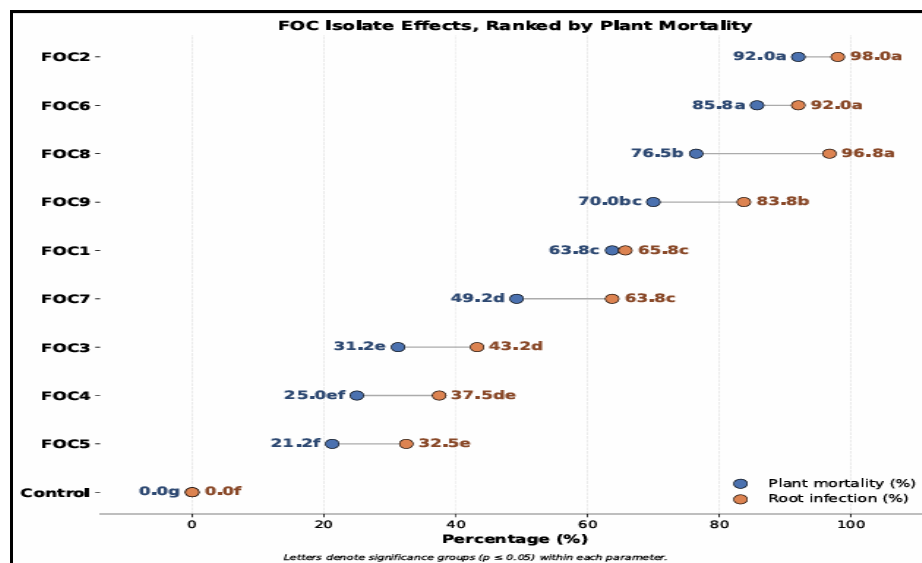


Figure 5. Plant mortality and root infection (%) caused by nine FOC isolates on cucumber cv. Mawasem. Mean values marked with different letters show significant differences (LSD test, $p < 0.05$).

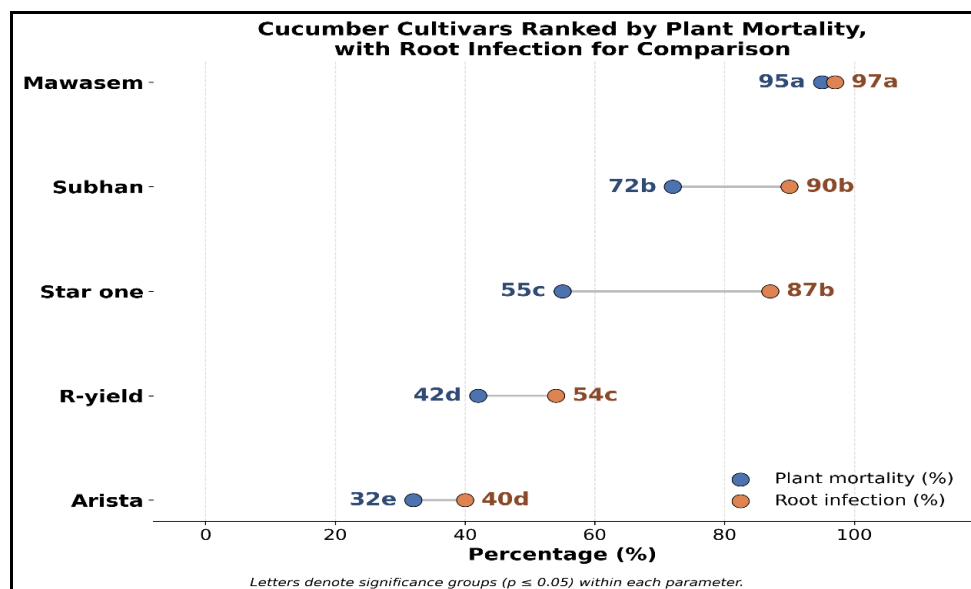


Figure 6. Plant mortality and root infection (%) of five cucumber cultivars inoculated with FOC2.

Reaction of cucumber cultivars to isolate FOC2: All five cultivars were susceptible to FOC2 but differed significantly in degree. Mortality ranged from 32.25% (Arista) to 95.00% (Mawasem), with Subhan (72.00%), Star One (55.00%) and R-Yield (42.00%) intermediate; root infection followed the same pattern (40.00-96.50%) (Figure 6). With respect to the growth parameters: shoot length ranged from 6.05 cm

(Mawasem) to 34.00 cm (Arista), and shoot fresh weight from 2.90 g (Mawasem) to 7.77 g (Arista), with root length and weight following the same trend. In short, cultivars with the highest mortality and root infection (Mawasem, Subhan) showed the greatest suppression of shoot and root growth, whereas the comparatively less susceptible cultivars (Arista and R-Yield) maintained comparatively better growth despite infection (Figure 7)

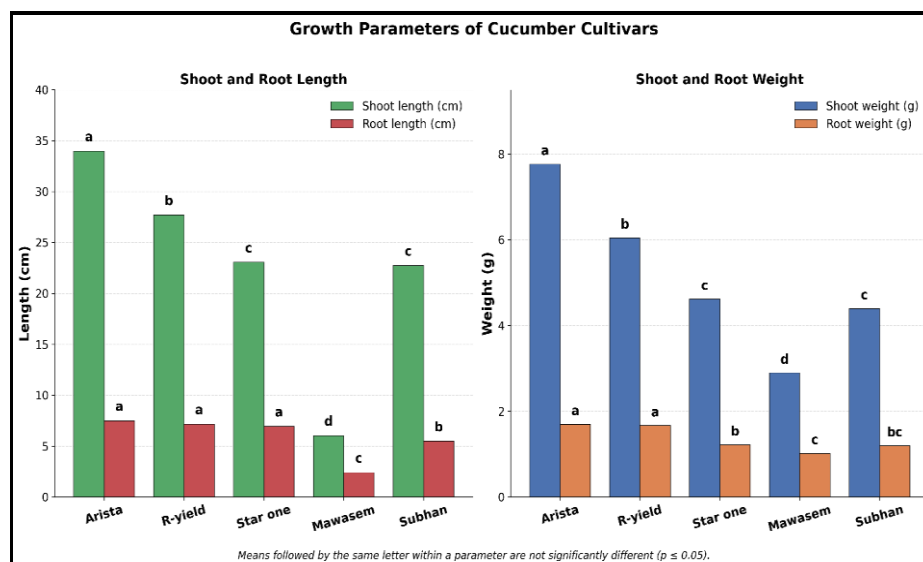


Figure 7. Shoot and root length (left) and shoot and root weight (right) of five cucumber cultivars following FOC2 inoculation.

DISCUSSION

The survey shows that *Fusarium* wilt is now well established in the surveyed tunnel-based cucumber production areas of Balochistan, with incidence reaching 57.20% in the most heavily affected tunnels. The highest disease pressure was recorded in Quetta, the district with the longest history of continuous tunnel cucumber cultivation. This pattern may reflect repeated mono-cropping, which has been reported elsewhere to promote the build-up of soil-borne inoculum and secondary salinization, both of which favour *Fusarium* wilt development (Meng *et al.*, 2018; Wang *et al.*, 2021), while restricted drainage and high humidity inside plastic tunnels are similarly reported to favour pathogen survival and spore formation (Everhart *et al.*, 2010); soil inoculum density, salinity, and tunnel humidity were not directly measured in the present study, and this explanation should therefore be regarded as plausible rather than confirmed. These incidence levels are broadly consistent with the 40-70% yield losses reported from other intensively cultivated cucumber-producing regions (Vakalounakis *et al.*, 2004; Sharma and Shukla, 2021).

The consistent recovery of a single, morphologically uniform fungal species from infected tissue at every location, which reproduced typical wilt symptoms on re-inoculation, supports its morphological identification as *F. oxysporum*, consistent with the description of Leslie and Summerell (2006) and the approach used by Din *et al.* (2020). Because morphological characters alone cannot reliably distinguish formae speciales within *Fusarium oxysporum*, the *cucumerinum* designation used throughout this study should be regarded as provisional; molecular confirmation such as ITS or TEF1- α sequencing is recommended before this identification is treated as definitive.

All nine isolates were pathogenic but differed noticeably in aggressiveness, with mortality ranging

from 21.25 to 92.00% between the least and most aggressive isolates. Such diversity in FOC aggressiveness has also been reported previously (Moretti *et al.*, 2011; Al-Tuwaijri, 2015; Beckman, 2017). The isolates classified as highly pathogenic in the present study, particularly FOC2, represent useful reference material for future screening, resistance-breeding and biocontrol studies in the region. Among the five commercial cultivars tested against FOC2, none was resistant, although susceptibility differed significantly, with Arista and R-Yield comparatively less susceptible than Mawasem. A single isolate (FOC2) was only used in the cultivar-screening trial, these reaction patterns should be interpreted as isolate-specific rather than indicative of broad-spectrum resistance or susceptibility, since cultivar performance can vary considerably against different isolates of the same pathogen. The tendency of susceptible cultivars to combine high mortality and root infection with pronounced growth suppression is consistent with previous reports that cultivars able to restrict vascular pathogen spread also show comparatively reduced growth losses under *Fusarium* wilt pressure (Cho and Muehlbauer, 2004; Djebali *et al.*, 2009; Al-Tuwaijri, 2015; Din *et al.*, 2020). *Fusarium oxysporum* persists in soil for extended periods and is difficult to eradicate once established (Wang *et al.*, 2012; Dean *et al.*, 2012). Among the five cultivars evaluated here, none showed resistance to FOC2, which is of practical concern for growers currently relying on these particular cultivars; broader screening across additional cultivars and isolates would be needed before conclusions can be drawn about resistance across Balochistan's cucumber germplasm more generally. Cultivar resistance nonetheless remains one of the more sustainable long-term management options where it can be identified (Hulbert *et al.*, 2001; Nazar *et al.*, 2018; Sharma and Shukla, 2021).

CONCLUSION

These findings indicate that Fusarium wilt is an important disease constraint in the surveyed cucumber tunnels of Balochistan, with incidence reaching over 57% in the most severely affected tunnels across Quetta, Pishin and Mastung districts. Nine pathogenic isolates were recovered and characterized, varying substantially in aggressiveness, with FOC2 identified as the most aggressive isolate. All five commercial cultivars evaluated were susceptible to FOC2, although Arista and R-Yield showed comparatively lower susceptibility. These results indicate Fusarium wilt as a significant threat to tunnel cucumber production in the surveyed districts and highlight the absence of adequate resistance among the cultivars evaluated in this study.

RECOMMENDATIONS

Growers in high-incidence regions, particularly Quetta district, may benefit from avoiding continuous cucumber monocropping and adopting rotation with non-host species, a practice reported elsewhere to reduce soil-borne inoculum build-up. Since Arista and R-Yield showed comparatively lower susceptibility specifically to isolate FOC2 in this study, further evaluation against additional isolates and locations is recommended before they can be more broadly recommended for high-risk tunnels. Molecular characterization (ITS/TEF1-alpha sequencing) of the isolates is recommended to confirm forma-specialis identity and enable public sequence deposition.

AUTHORS' CONTRIBUTIONS

A.B: Conducted this research, analysed the data and prepared the manuscript for publication. S. A. Helped in the execution of tunnel experiment. S.A.U.R. Assisted in conducting experiments and writing the first draft of the manuscript. A.H. Designed the experimental trials. M.A. Drafted a part of the manuscript. M. H. Revised the final version of the manuscript.

CONFLICT OF INTEREST

All authors have read and agreed to the published version of the manuscript and the authors declare no conflict of interest.

REFERENCES

Agrios, G.N. (2005). Plant Diseases Caused by Fungi. In: Plant Pathology, Elsevier, Amsterdam, pp. 385-614.
Al-Tuwaijri, M.M. (2015). Studies on Fusarium wilt disease of cucumber. *Journal of Applied Pharmaceutical Science*, 5(2), 110-119.
Beattie, G.A. (2011). Water relations in the interaction of foliar bacterial pathogens with plants. *Annual Review of Phytopathology*, 49(1), 533-555.
Beckman, C.H. (2017). *The Nature of Wilt Disease of Plants*. APS Press.
Cheng, F., Ali, M., Liu, C., Deng, R., & Cheng, Z. (2020). Garlic allelochemical diallyl disulfide alleviates autotoxicity in the root exudates caused by long-term continuous cropping of

tomato. *Journal of Agricultural and Food Chemistry*, 68, 11684-11693.
Cho, S., & Muehlbauer, F.J. (2004). Genetic effect of differentially regulated fungal response genes on resistance to necrotrophic fungal pathogens in chickpea (*Cicer arietinum* L.). *Physiological and Molecular Plant Pathology*, 64(2), 57-66.
Dauda, N., Adewuyi, O. S., Ishieze, U. P., Ugwuoke, K. I., & Ukwu, U. N. (2022). Farmer's unseen enemy: Soilborne pathogens and its' management. *Nigerian Journal of Horticultural Science*, 26(4), 96-106.
Dean, R., Van Kan, J.A.L., Pretorius, Z.A., Hammond-Kosack, K.E., Di Pietro, A., Spanu, P.D., et al. (2012). The Top 10 fungal pathogens in molecular plant pathology. *Molecular Plant Pathology*, 13(4), 414-430.
Din, H.M., Rashed, O., & Ahmad, K. (2020). Prevalence of Fusarium wilt disease of cucumber (*Cucumis sativus* Linn) in peninsular Malaysia caused by *Fusarium oxysporum* and *F. solani*. *Tropical Life Sciences Research*, 31(3), 29-45.
Djebali, N., Jaoua, S., & Gargouri, R. (2009). Fusarium wilt of cucumber: causes and breeding for resistance. *Plant Pathology Journal*, 8(2), 49-59.
Everhart, E., Hansen, R., Lewis, D., Naeve, L., & Taber, H. (2010). Iowa high tunnel fruit and vegetable production manual. *Iowa State University Extension Manual PM*, 2098.
Govt. of Pakistan. (2025). Fruits, Vegetables and Condiments Statistics of Pakistan, 2023-24. Economic Wing, Ministry of National Food Security and Research, Islamabad.
Hulbert, S.H., Webb, C.A., Pryor, A., & Kliebenstein, D.J. (2001). Resistance gene effectiveness and the role of gene-for-gene interactions in disease management. *Journal of Plant Pathology*, 83(1), 30-39.
Kumar, P., Sharma, N., Sharma, S., & Gupta, R. (2020). Rhizosphere stoichiometry, fruit yield, quality attributes and growth response to PGPR transplant amendments in strawberry (*Fragaria ananassa* Duch.) growing on solarized soils. *Scientia Horticulturae*, 265, 109215.
Leslie, J.F., & Summerell, B.A. (2006). *The Fusarium Laboratory Manual*. Blackwell Publishing.
Meng, L., Yao, X., Yang, Z., Zhang, R., Zhang, C., Wang, X., & Zheng, C. (2018). Changes in soil microbial diversity and control of *Fusarium oxysporum* in continuous cropping cucumber greenhouses following biofumigation. *Emirates Journal of Food and Agriculture*, 30(8), 644-653.
Moretti, A., Migheli, Q., & Mastro, A. (2011). Fusarium graminearum and Fusarium head blight. *Plant Disease*, 95(2), 185-192.
Nazar, R., Iqbal, M., & Bibi, H. (2018). Cultivar susceptibility to Fusarium wilt in cucumbers. *Journal of Plant Pathology*, 100(1), 75-83.
Nema, N.K., Maity, N., Sarkar, B., & Mukherjee, P.K. (2011). *Cucumis sativus* fruit-potential antioxidant, anti-hyaluronidase, and anti-elastase agent. *Archives of Dermatological Research*, 303(4), 247-252.
Okungbowa, F.I., & Shittu, H.O. (2012). Fusarium wilts: an overview. *Environmental Research Journal*, 6(2), 83-102.
Sharma, S., Dwivedi, J., & Paliwal, S. (2012). Evaluation of antacid and carminative properties of *Cucumis sativus* under simulated conditions. *Scholars Research Library Der Pharmacia Lettre*, 4(1), 234-239.
Sharma, V., Sharma, L., & Sandhu, K.S. (2020). Cucumber (*Cucumis sativus* L.). In: Antioxidants in Vegetables and Nuts - Properties and Health Benefits. Springer, Singapore, pp. 333-340.
Sharma, D., & Shukla, A. (2021). Fusarium wilt of cucumber - a review. *International Journal of Economic Plants*, 8(4), 193-200.
Shen, W., Lin, X., Gao, N., Zhang, H., Yin, R., Shi, W., & Duan, Z. (2008). Land use intensification affects soil microbial populations, functional diversity and related suppressiveness of cucumber Fusarium wilt in China's Yangtze River Delta. *Plant and Soil*, 306(1), 117-127.
Sotiroidis, G., Melliou, E., Sotiroidis, R.G., & Chinou, I. (2010). Chemical analysis, antioxidant and antimicrobial activity of three Greek cucumber (*Cucumis sativus*) cultivars. *Journal of Food Biochemistry*, 34, 61-78.

- Summerell, B.A., Salleh, B., & Leslie, J.F. (2003). A utilitarian approach to *Fusarium* identification. *Plant Disease*, **87**(2), 117-128.
- Tariq, M., Ali, M., & Yasin, A. (2020). Cucumber cluster feasibility and transformation study. In: Ali Mubarik (Ed.), Cluster Development Based Agriculture Transformation Plan. CABI, Rawalpindi, Pakistan.
- Uthpala, T.G.G., Marapana, R., Lakmini, K., & Wettimuny, D. (2020). Nutritional bioactive compounds and health benefits of fresh and processed cucumber (*Cucumis sativus* L.). *Sumerianz Journal of Biotechnology*, **3**, 75-82.
- Vakalounakis, D.J., Wang, Z., Fragkiadakis, G., Skaracis, G., & Li, D.B. (2004). Characterization of *Fusarium oxysporum* isolates obtained from cucumber in China by pathogenicity, VCG, and RAPD. *Plant Disease*, **88**(6), 645-649.
- Vargas-Inciarte, L., Fuenmayor-Arrieta, Y., Luzardo-Mendez, M., Costa-Jardin, M.D., Vera, A., Carmona, D., & San-Blas, E. (2019). Use of different *Trichoderma* species in cherry type tomatoes (*Solanum lycopersicum* L.) against *Fusarium oxysporum* wilt in tropical greenhouses. *Agronomia Costarricense*, **43**, 85-100.
- Wang, M., Ling, N., Dong, X., Zhu, Y., Shen, Q., & Guo, S. (2012). Thermographic visualization of leaf response in cucumber plants infected with the soil-borne pathogen *Fusarium oxysporum* f. sp. *cucumerinum*. *Plant Physiology and Biochemistry*, **61**, 153-161.
- Wang, H., Cai, X.Y., Xu, M., & Tian, F. (2021). Enhanced biocontrol of cucumber *Fusarium* wilt by combined application of new antagonistic bacteria *Bacillus amyloliquefaciens* B2 and phenolic acid-degrading fungus *Pleurotus ostreatus* P5. *Frontiers in Microbiology*, **12**, 700142.

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