The Pharma Innovation Journal 2023; SP-12(9): 112-115

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(9): 112-115

www.thepharmajournal.com
Received: 11-07-2023
Accepted: 21-08-2023

Katravath Srinivas
Professor, Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana, India

Mamta Sharma
Department of Legumes Pathology, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Greater Hyderabad, Telangana, India

Gali Umadevi
Professor, Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana, India

CV Sameer Kumar
Professor, Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana, India

SNCVL Puspavalli
Professor, Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana, India

Corresponding Author:
Katravath Srinivas
Professor, Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana, India

Unraveling *Fusarium* Wilt: In-depth survey of chickpea in South India's agroecosystems

Katravath Srinivas, Mamta Sharma, Gali Umadevi, CV Sameer Kumar and SNCVL Puspavalli

Abstract
During the 2021-2022 rabi cropping season, a survey was undertaken to gather data on the prevalence and spread of chickpea diseases in relation to factors such as soil type, cultivated variety, and seed treatment in central and southern regions of India. The majority of farmers (28% - 49%) relied on local cultivars, while 68% employed seed treatment with fungicide. Diseases like *Fusarium* wilt, dry root rot, and collar rot were identified across all sites, with their occurrence ranging from 5.5% to 20%, 2% to 30%, and 1% to 9%, respectively, regardless of cultivar and location. The study also noted the presence of black root rot disease in the surveyed states. These findings highlight the widespread prevalence of dry root rot and collar rot, in addition to *Fusarium* wilt, among chickpea crops in the southern regions of India. As such, it is imperative to explore potential management strategies to address this issue.

Keywords: Chickpea, cultivars, fungi, disease, survey, South India, yield

1. Introduction
Chickpeas hold significant economic importance due to their widespread cultivation and consumption. They are a valuable source of plant-based protein, contributing to both human and animal nutrition. The global chickpea market supports livelihoods for farmers worldwide and fosters rural economies. Globally, chickpeas are cultivated across 14.56 million ha, yielding 14.78 million tons at an average of 1014.60 kg/ha. In India, they're grown over 15 M ha, producing 15.87 M t with an average yield of 1058 kg/ha (FAOSTAT, 2021; Agricultural Statistics at a Glance, 2021) [3, 1]. Chickpeas' versatility in various cuisines and their use in processed foods like hummus and snacks further drive their demand and economic value. Additionally, chickpea cultivation can improve soil health through nitrogen fixation, reducing the need for synthetic fertilizers and benefiting agricultural sustainability.

Chickpea *Fusarium* wilt disease holds significant economic importance due to its potential to cause substantial yield losses. The disease is caused by the soil-borne fungus *Fusarium* oxysporum, leading to wilting, stunted growth, and reduced seed production in chickpea plants. This can result in decreased crop quality and market value. Management strategies, such as crop rotation and resistant cultivars, are often required to mitigate its impact, incurring additional costs for farmers. The disease's ability to persist in soil for extended periods further underscores its economic impact by limiting land usability and increasing the need for sustainable management practices (Nene *et al*., 1996) [5].

Chickpea *Fusarium* wilt disease, caused by the fungus *Fusarium* oxysporum, has been a persistent concern worldwide (Nene *et al*., 1989) [6]. Surveys conducted over decades reveal its widespread occurrence in major chickpea-growing regions like Asia, Africa, and the Americas. These surveys documented varying levels of disease incidence and severity, often leading to significant yield losses (Pande *et al*., 2010) [8]. Researchers have been striving to identify resistant cultivars and implement effective management practices, such as crop rotation and soil sterilization, to mitigate its impact. Despite ongoing efforts, the disease remains a challenge for chickpea cultivation in diverse regions.

Fusarium wilt of chickpea, caused by the soil-borne fungus *Fusarium* oxysporum f. sp. ciceris, has been a concern in India since the 1970s. The disease severely affects chickpea crops, leading to yield losses (Pande *et al*., 2004) [9]. Early surveys conducted in the 1980s identified the disease in various chickpea-growing regions across the country. Over the years, researchers have conducted extensive surveys to monitor the disease's prevalence and understand its genetic diversity.

These efforts have contributed to the development of disease-resistant chickpea varieties and management strategies to mitigate the impact of *Fusarium* wilt on India's chickpea production (Nikam *et al*., 2011; Singh & Sirohi, 2003) [7, 10].
Various methods of surveying chickpea *Fusarium* wilt disease globally include visual field assessments, where observers identify wilt symptoms in chickpea crops. Additionally, molecular techniques, such as polymerase chain reaction (PCR), are used to detect the presence of the *Fusarium* pathogen in plant tissues. Remote sensing technologies, like satellite imagery, can aid in identifying disease hotspots. Serological tests help detect specific antigens related to the pathogen. Lastly, surveys often incorporate farmer interviews to gather insights into disease prevalence and management practices. These methods collectively provide a comprehensive understanding of the disease's distribution and impact.

2. Materials and Methods

2.1. Areas Surveyed

The survey took place from December to March 2021-2022 in the primary chickpea cultivating states of southern India, namely Telangana, Andhra Pradesh, and Karnataka (shown in Figure 1). Random district selection was done in each region. In total, 24 fields across 12 districts were surveyed. Two fields were visited per district, with a distance of 20-25 km between sites (Ghosh *et al*., 2013) [4]. However, districts with more distant chickpea fields had greater distances between sites, leading to fewer sites being visited in those districts.

2.2. Data Collection

A survey form utilizing the Global Positioning System (GPS) was created to gather data from farmers. This data included details about disease occurrence, soil characteristics, crop growth stage, planting arrangement, fungicide usage for seed treatment, cultivated plant types, and information about each sampled chickpea plant such as its variety name (whether local or improved). Additionally, the GPS coordinates of each sampling point were logged.

2.3. Data analysis Three

A square area measuring 1x1 meter was randomly chosen within fields across four surveyed states. Within each square, the number of infected plants was counted. Using the counts of infected and total plants, the disease incidence (DI) was calculated. This disease incidence for each field contributed to the district's average, which then influenced the overall average for each state. These averages show the proportional presence of chickpea diseases in the surveyed locations. The data collected for various factors like cultivar type, soil type, and seed treatment were averaged to determine the mean value for each factor.

3. Results and Discussion

3.1. Cultivars and Incidence

Farmers in Telangana, Andhra Pradesh, and Karnataka cultivated a total of 8 different types of chickpea, both local and improved. Among these, 25% of farmers exclusively grew local varieties, while the remaining 75% opted for improved types. Annigeri and Harbora were the most commonly cultivated local varieties, whereas JG 11 stood out as the favored improved variety. In the case of Karnataka farmers, a significant proportion preferred local varieties, followed by those in Andhra Pradesh. Disease occurrence was less frequent in improved varieties compared to local ones, with local types showing a higher frequency of moderate to severe symptoms. Interestingly, among the improved types, the Jawahar cultivar had a higher disease incidence percentage compared to other improved cultivars in Karnataka.

3.2. Diseases and Regions

Field investigations conducted in three states revealed that *Fusarium* wilt, dry root rot (DRR), and collar rot (CR) were the prevailing issues across all fields. Another observed symptom was the distribution of black root rot (BRR), which is attributed to *Fusarium solani*. The type of soil did not show any noteworthy impact on the occurrence of these diseases in the surveyed regions.

3.2.1. Andhra Pradesh and Telangana

In both Andhra Pradesh and Telangana, all four diseases (*Fusarium* wilt, collar rot, dry root rot, and black root rot) were detected. The local cultivar experienced a greater occurrence of wilt disease compared to the improved cultivar (Fig. 2). The incidences of dry root rot and collar rot were nearly the same across different cultivars (local or improved) and soil types. Black root rot disease was present in all fields in Andhra Pradesh, regardless of the type of cultivar. Treating seeds with the fungicide Bavistin resulted in a higher proportion of plants exhibiting lower occurrences of all diseases, compared to untreated plants.

3.2.2. Karnataka

In Karnataka, all four illnesses *Fusarium* wilt, collar rot, dry root rot, and black root rot—were identified. The native cultivar exhibited a greater occurrence of wilt disease compared to the enhanced cultivar. The incidence of DRR and CR diseases was nearly identical regardless of the type of cultivar (native or improved) or soil composition. Treating seeds with the fungicide Bavistin resulted in a higher number of plants with lower disease incidence compared to untreated plants. The presence of BRR disease was observed at a low percentage in local cultivars within certain areas of Karnataka
This research is the first to thoroughly investigate the significance of fungal infections affecting chickpeas in southern India when compared to other chickpea diseases in these regions. The survey findings ranked wilt as the most prevalent among the four chickpea diseases studied, followed by DRR, CR, and BRR (Fig. 3). These diseases were identified as notable issues for chickpea cultivation in the southern parts of India.
The study revealed that wilt and BRR diseases were mainly limited to local and moderately resistant chickpea varieties, regardless of soil types. The distribution of BRR disease was noted in all three surveyed states of Telangana, Andhra Pradesh, and Karnataka. Several factors, including resistance, unfavorable environmental conditions, and increased fungicide-treated seeds, could explain the low presence of BRR in Karnataka (Pande *et al*., 2010) [8]. DRR and CR were widespread across all chickpea varieties in all four states, regardless of farmer preferences. Their incidence varied between 2% to 30% and 1% to 9%, respectively (Table 1). Moisture stress and high temperatures in southern India likely contributed to the favorable conditions for DRR.
Economic significance of these diseases was evident from the survey results. Susceptibility of chickpea cultivars in southern India to these pathogens could explain the elevated disease

risks. Despite collecting cultivar information, resistance scores for DRR and CR were unavailable. Limited research on *R. bataticola* pointed to the importance of temperature and moisture stress for its infection (Pande *et al*., 2004) [9]. Local cultivars exhibited higher disease incidence and severity compared to improved varieties across all states. Due to the absence of resistance sources, both DRR and CR were present in all fields regardless of the cultivar (Akram *et al*., 2008; Pande *et al*., 2010) [2, 8]. Increasing use of seed treatments might have contributed to the reduced disease prevalence.

Table 1: Disease incidence of *Fusarium* wilt during the year's 2021 and 2022 south India

District	Disease incidence 2021	Disease incidence 2022
Adilabad	6.33	5.50
Nizamabad	8.165	6.84
Mahabubnagar	13.835	12.83
Rangareddy	10.335	12.00
Medak	7	7.50
Kurnool	14.67	14.34
Anantpur	19.835	18.67
Dharwad	14.665	14.17
Raichur	12.665	12.17
Bijapur	9.67	7.67
Kalaburagi	9.83	7.67
Bidar	7.00	6.00

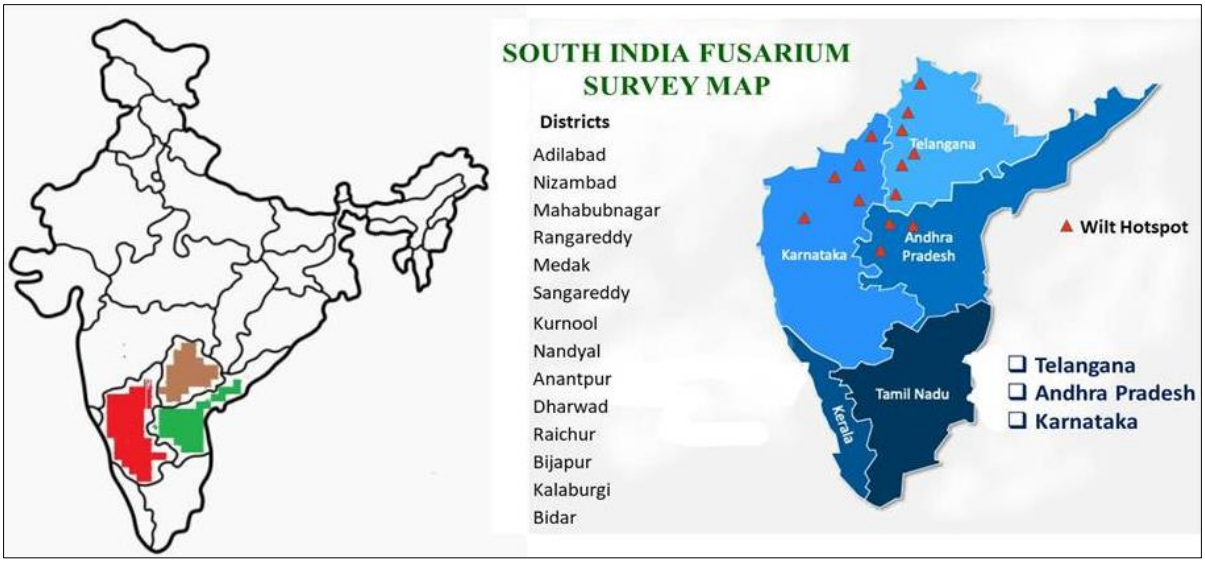

Fig 1: Surveyed sites in the chickpea growing season of 2021-2022.

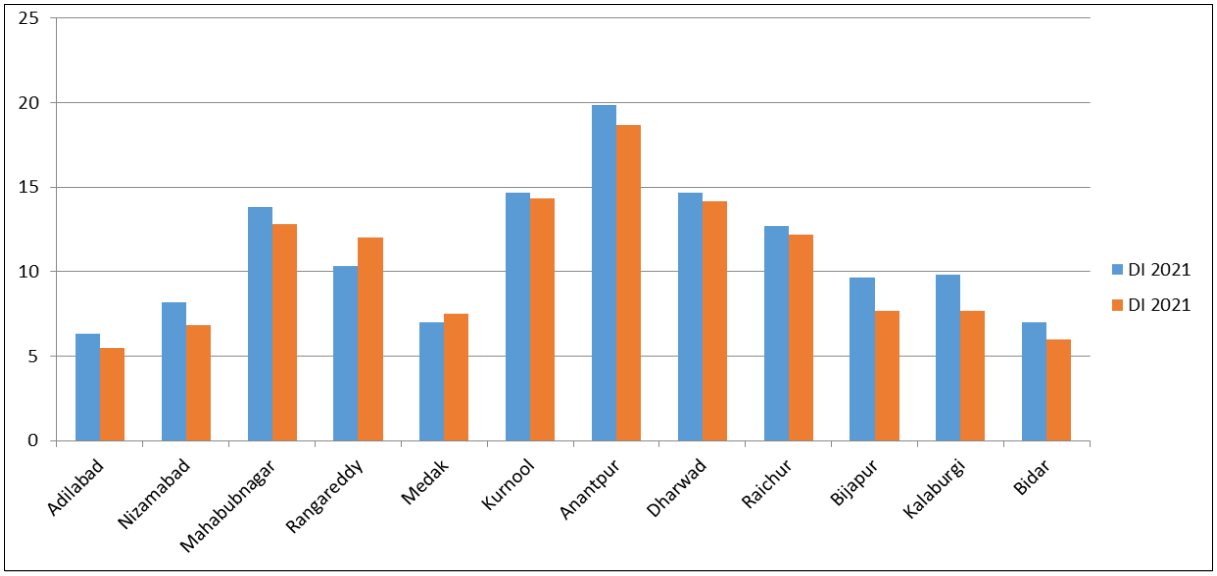

Fig 2: Comparing the occurrence of *Fusarium* wilt in the years 2021 and 2022

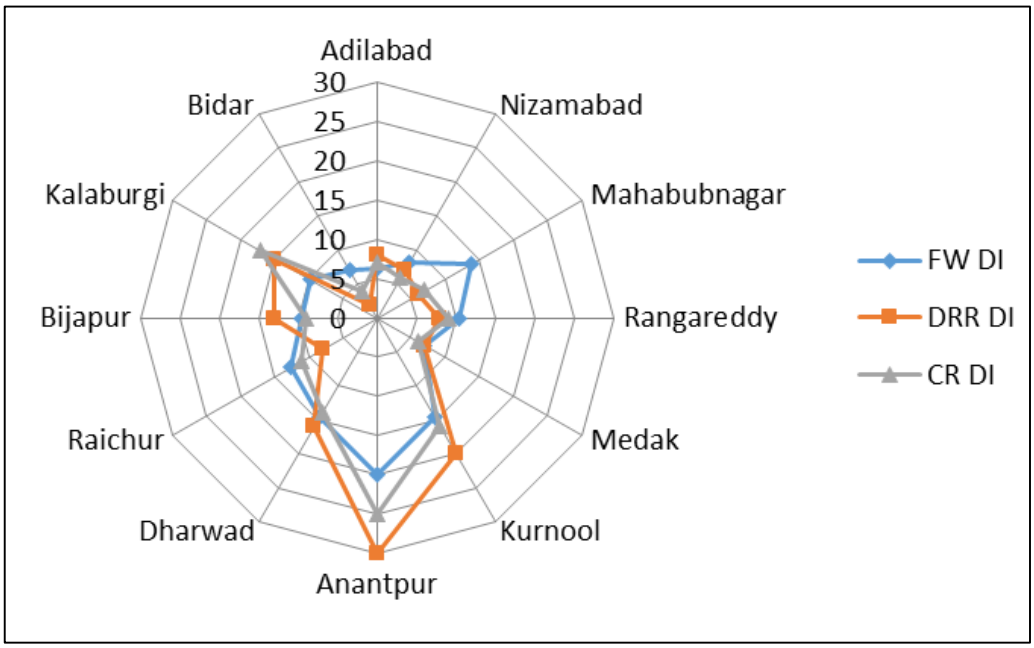

Fig 3: Examining the varying occurrence rates of three diseases within states in South India

4. Conclusion

The occurrence and prevalence of soil-borne illnesses in chickpeas differed across different states. Diseases like DRR and CR are becoming a significant danger to chickpea crops. It's important to create chickpea varieties that can resist multiple diseases, including wilt, DRR, CR, and BRR. Understanding the reasons behind the widespread presence of these diseases requires more in-depth research.

5. Acknowledgement

The work has been undertaken as part of the Doctoral research program at the Department of Legume Pathology, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Greater Hyderabad, Telangana. This institution has an MOU with Professor Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad. The first author is a research scholar, and the second author, being a chairman, is thankful to ICRISAT for providing facilities to conduct the work.

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