Journal of Food Legumes
38(4): 493-505, 2025
DOI: 10.53550/jfl.v38.i4.298

Review Paper

Chickpea fusarium wilt: A review of predominant challenge to chickpea production in Ethiopia

Abebe Yilma[1]*, Merkuz Abera[2], Berhanu Bekele[3], Tesfaye Alemu[4] and Ramesh R Vetukuri[5]

[1]*Department of Horticulture, College of Agriculture, Food and Climate Sciences, Injibara University, Ethiopia*
[2]*Department of Plant Sciences, College of Agriculture and Environmental Sciences, Bahir Dar University, Ethiopia*
[3]*Ethiopian Institute of Agricultural Research, Ambo Agricultural Research Center, Ethiopia*
[4]*Department of Microbial Sciences and Genetics, College of Natural and Computational Sciences, Addis Ababa University, Ethiopia*
[5]*Department of Plant Breeding, Swedish University of Agricultural Sciences, Alnarp, Sweden*

**Corresponding author e-mail:* *abebalem2005@gmail.com*

Received: *June 26, 2025*
Accepted: *December 3, 2025*

ABSTRACT

Chickpea Fusarium wilt is a major challenge to chickpea production in Ethiopia, impacting yields across agro-ecological zones. This review synthesizes current knowledge on the disease's distribution, disease pressure, pathogenic variability, and various management practices within the country. The objective was to provide a comprehensive overview of chickpea Fusarium wilt in Ethiopia and to evaluate current management strategies. Data were compiled from peer-reviewed publications, research reports, and surveys conducted between 2008 and 2025. The review highlights the wide-spread occurrence of the disease, with incidence rates ranging from 5% to 58% and severity indices from 3% to 42% across major chickpea-producing regions. In the Amhara region, where the disease pressure is impactful, more than 65% of the surveyed districts retained a mean wilt incidence of above 25%. The pathogenic diversity of *F. oxysporum* f.sp. *ciceris* is substantial, with isolates exhibiting varying degrees of virulence. Sustainable and effective management necessitates an integrated approach, incorporating agronomic practices and cropping systems, including delayed planting, intercropping and cereal-based long-term crop rotation. Application of bio-control agents that consist *Psudomonas*, *Trichoderma*, and *Bacillus* species is pivotal against Fusarium wilt in chickpea. Host resistance, including the use of Arerti, Mastewal, Natoli, and Chefe varieties and fungicides like Goldazim 500SC, Carbondazim, Apron star, Thiram, Thio-phanate-methyl and Mancozeb alone or in combination, significantly reduced the Fusarium wilt intensity.

Key words: *F. oxysporium* f.sp. *ciceris*, Incidence, Integrated management, Severity

INTRODUCTION

Chickpea (*Cicer arietinum* L.) ranks as the third most valuable cool-season food legume in terms of production, next to common bean (*Phaseolus vulgaris* L.) and peas (*Pisum sativum* L.) globally (Merga and Haji 2019). Its annual production exceeds 18.1 mt (Charitha *et al.* 2025) and is cultivated on approximately 15 m ha globally during the 2022- 23 cropping seasons. This crop accounts for over 20% of the world's pulse production, with only dry beans and peas surpassing it in terms of volume (Patra and Kumar Biswas 2017). India is the leading producer, accounting for 65% of global production, followed by Myanmar at 14% (FAOSTAT 2020). Ethiopia stands as the third largest producer, contributing 4% to the global output and 90% total output in Sub-Saharan Africa (Verkaart *et al.* 2017).

Chickpea contribute significantly to the diet of human nutrition, serving as an excellent source of essential fiber, vitamins, carbohydrates, mineral salts, unsaturated fatty acids and β-carotene (Shevkani *et al.* 2019). It is also regarded as one of the most crucial food legumes, offering a good source of affordable source of protein, calcium, iron, phosphorus, and various other nutrients (Fikre and Bekele 2020, Kumar *et al.* 2023). This is especially vital for millions of people in developing countries (Merga and Haji 2019, Nasr Esfahani *et al*. 2014. Rocha *et al*. 2024). It has a significant contribution to the food security of lower-income countries like Ethiopia and is a fundamental element of small-scale farming (Varshney *et al.* 2014). This leguminous crop is also crucial for effective soil fertility management, as it possesses the exceptional ability to undergo atmospheric nitrogen fixation. The use of chickpea in farming systems, as a fundamental unit, would result in enhancing total output, alleviating the risk of crop failure, ensuring long-lasting agricultural production efficiency, increasing profitability, and streamlining resource use effectively and efficiently (Fikre *et al*. 2020, Richards *et al*. 2022).

In Ethiopia, where 90% of chickpea production is achieved in Sub-Saharan Africa, it is a revenue-generating, valuable pulse crop produced by about 1,000,000 small-scale farmers (Korbu *et al.* 2022). Chickpea can substantially impact Ethiopia's agricultural development and have the capacity to be a principal driver of economic performance in the country (Mulat *et al*. 2022). Despite its significance for economic stability and food security in Ethiopia, it experiences alarmingly low average productivity levels, currently approximately 2 tons per hectare (CSA 2023). This productivity falls far short of its potential of 5 t ha^{-1} (Keneni *et al.* 2012, Verkaart *et al.* 2017). This lower productivity of chickpea in Ethiopia is mainly attributed to a shortage of improved and good-quality seeds, various diseases, and insect pests (Mulat *et al*. 2022). Chickpea experienced significant biotic stresses, with diseases proving to be the most significant yield-limiting constraints (Venkataramanamma *et al.* 2023).

Chickpea Fusarium wilt, incited by the fungal pathogen *Fusarium oxysporum* f.sp. *ciceris* is a widespread and leads to major cause of yield losses in numerous chickpea growing nations globally (Dubey *et al.* 2010, Venkataramanamma *et al.* 2023). This widespread and damaging disease has led to reduced chickpea yield harvest in many chickpea-growing regions in Ethiopia, as evidenced by studies conducted by Bekele *et al*. (2021) and Yimer *et al.* (2018). For instance, Meki *et al.* (2008) reported about a 30% decrease in chickpea grain due to chickpea Fusarium wilt interference under Ethiopian conditions, showcasing its considerable impact on chickpea production. Furthermore, (Mengist *et al.* 2018) reported that relative grain yield losses due to chickpea Fusarium wilt were escalated to 95.38% in the untreated local chickpea variety compared to treated plots under sick plot conditions in west Gojjam. It is described as one of the most destructive diseases, inducing an estimated mean annual yield loss ranging from 10-90% under Ethiopian conditions based on favorable biophysical factors like atmospheric humidity and temperature (Alefe *et al*. 2022, Mengist *et al*. 2018). Apart from direct grain yield loss, it also resulted in secondary effects such as the production of lower-quality seeds (Alsamman *et al*. 2023, Navas-Cortes *et al*. 2000). Seeds sourced from wilted chickpea plants are often lighter, rougher, duller, and less likely to produce viable seeds than those harvested from healthy chickpea plants (Navas-Cortes *et al*. 2000). Addressing this challenge is crucial for sustainable management, which relies heavily on an integrated management approach.Therefore, the current review aims to provide valuable insight into chickpea *Fusarium* wilt epidemics, their pathogenic variability and potentially available management practices.

IMPORTANCE AND EXPANSION POTENTIAL OF CHICKPEA

Chickpea is highly versatile, serving various purposes from food and animal feed to nutritional enhancements, market commodities, homemade preparations and healthy-focused diets**.** It is uniquely suited to small-scale farming and promotes gender inclusivity, as it can be cultivated in backyard gardens for household use to medium-sized production for both family consumption and market sales, and even at large commercial production and broader market distribution (Fikre *et al.* 2020, Tabe-Ojong and Mausch 2017). Chickpea is a multipurpose legume crop that can be integrated into various cropping systems, including double, relay and rotational cropping, alongside cereals like maize, sorghum, wheat, teff, sorghum rice and millet (Jemberu *et al.* 2018)**.** Chickpea is also well adapted to double-cropping regions,where it can successfully reproduce by relying on the progressively depleting residual moisture in the soil (Jemberu *et al.* 2018, Korbu *et al.* 2020).

Chickpea possess a deep root system, enabling them to extract residual moisture efficiently left behind by previous crops. Besides, it disrupts pest cycles and enriches the soil with nitrogen as it possesses nitrogen fixation potential, making the ground more suitable for upcoming cereal cultivation (Fikre *et al*. 2020). It fixes approximately 140 kg ha^{-1} atmospheric nitrogen through symbiotic rhizobium bacteria residing in their root nodules (Hailemichael 2020). Growing chickpea reduces the nitrogen fertilizer requirement of the following cereal crop by at least one-third. Fixing atmospheric nitrogen naturally reduces the cost incurred for chemical fertilizer by up to $20 per hectare, while also offering an environmentally friendly and pollution-free alternative.

The inclusion of chickpea in farming systems, as a fundamental unit, would result in enhancing total output, alleviating the risk of crop failure, ensuring long-lasting agricultural production efficiency, increasing profitability, and optimizing resources effectively and efficiently (Fikre *et al*. 2020, Richards *et al*. 2022). Chickpea role as a key component in various cropping systems results in a greater level of cumulative intensification (Gizaw, 2018). Implementing conservation agriculture-based crop production practices coupled with the recommended fertilization can improve maize–chickpea rotation yields, increase farm profitability, and enhance soil health, promoting long-term sustainable production (Pooniya *et al.* 2021). Wheat-chickpea double-cropping in Ethiopia achieved a high productivity, yielding 2.7 tons of wheat and 2.6 tons of chickpea per hectare within a single growing season. This efficient combination maximized land use, achieving a land equivalent ratio (LER) of 1.99, which signifies the maximization of yield and overall profit per unit area, highlighting the system's efficiency (Jemberu *et al.* 2018). Studies have shown the benefit of a 1:3 chickpea-teff rotation in Ethiopia, showing that this system sustainably achieves high productivity for both crops (Gizaw 2018). Chickpea is also a well-suited crop for an irrigated production system, offering the potential for significant yields.Research has shown that up to six chickpea generations per year are possible under irrigated field conditions, indicating high productivity per unit area and time (Asnake and Degefu 2019). This enhanced productivity is evident in Sudan, where irrigated chickpea yields exceed 3 tons per hectare (FAOSTAT 2020) and in Ethiopia, where yields reach approximately 3.2 tons per hectare (Girma *et al*. 2017).

CHICKPEA PRODUCTION TREND IN ETHIOPIA

The crop's status as an export commodity has undeniably driven this growth, as Ethiopian farmers, responding to market incentives, have gradually shifted towards chickpea cultivation. The upward trajectory in production has also been bolstered by an increasing understanding of the crop's environmental resilience, particularly in regions with limited precipitation. Ethiopia is one of the world's leading producers of chickpea, with production volume exceeding 401,000 metric tons in the year 2020/21 (CSA 2021). Ethiopia is also Africa's largest chickpea producer and exporter, accounting for about 3.5% of the global chickpea export market over the past two decades, significantly ahead of Tanzania's 1.7% (FAOSTAT 2020). While Ethiopia has experienced a gradual rise in the export volume of this particular crop, Ethiopia's export strategy is hampered by its heavy reliance on the low-value market segment, that nearly 94% are directed to itsexports. The market demonstrates a clear preference for kabuli chickpea types, evidenced by their 15% to 36% higher prices relative to desi types (Ferede *et al*. 2019). The total cultivated area and production contribution of Ethiopia to the African market are about 43% and 63%, respectively. Chickpea is identified as a promising avenue for simultaneously strengthening the agricultural sector and boosting the national economy (Mulat *et al*. 2022).

In Ethiopia, about 75% of the output is dedicated to domestic use, with the remaining quarter reaching commercial markets (CSA 2023). In countries where advanced agricultural technologies are implemented, about 82% of chickpea production is directed towards market distribution (Ferede *et al*. 2019). The shift from subsistence to market-driven chickpea farming in technology-adopted regions was enabled by the expanded application of agricultural innovations, notably through initiatives like the Tropical Legumes Project (Rubyogo *et al*. 2019). These projects introduced superior and high-quality chickpea varieties, characterized by desirable market attributes and increased productivity, thereby incentivizing farmers to transition towards commercial agriculture.

The trajectory of chickpea production in Ethiopia has witnessed a series of fluctuations, marked by periods of growth as well as setbacks, shaped largely by environmental, economic, and technological factors. As one of the preeminent producers of chickpeas in sub-Saharan Africa, Ethiopia consistently ranks among the top global producers, with its chickpeas forming an integral part of international markets, particularly in South Asia and the Middle East (Jendoubi *et al.* 2017, Rubyogo *et al.* 2019). A thorough analysis of Ethiopia's chickpea production trends provides invaluable insights into the future of this critical crop, as well as its broader implications for the country's agricultural development. In the past two decades, Ethiopia has experienced a noticeable upward trend in the acreage dedicated to chickpea cultivation. According to the Central Statistical Agency (CSA 2023), by 2023, over 470,000 hectares of land were allocated to chickpeas, reflecting both increased domestic consumption and burgeoning export demand. As Ethiopia continues to capitalize on the rising global demand for pulses, particularly from countries such as India, the area under chickpea cultivation has expanded, especially in key agricultural zones like Oromia, Amhara, and Tigray. However, its productivity is becoming diminishing due to many biophysical constraints, diseases are responsible for the lion's share (Mulat *et al.* 2022).

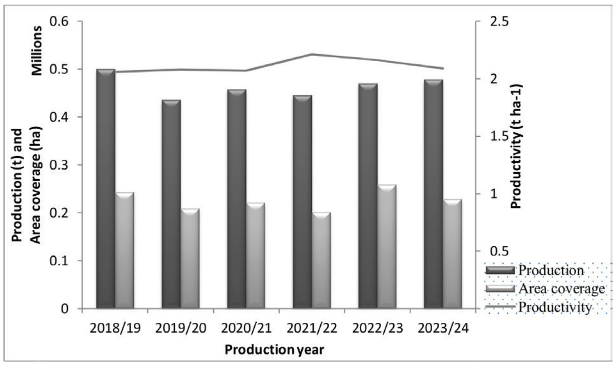

Fig. 1. Chickpea production trend showing volume of production, area coverage and productivity in the last six consecutive cropping seasons in Ethiopia (Source: CSA, 2018-2023/24)

THE CHICKPEA FUSARIUM WILT

Symptoms and host range

Chickpea Fusarium wilt emerges mainly in the form of root infections, in which the chlamydospores present on plant debris or in soil germinate, and mycelia penetrate into plant roots through natural openings (Besha 2021). After infection, it exhibits various symptoms, with the most common visible symptoms being wilting, yellowing, and discoloration of vascular tissue (Jendoubi *et al.* 2017, Ali and Terefe 2021, Younesi *et al.* 2021). *Fusarium oxysporum* f.sp. *ciceris* exhibits two pathotypes distinguished by their unique above-ground symptoms: one induces yellowing, and the other induces wilting symptoms in chickpea (Trapero-Casas A and Jimenez-Diaz RM 1985).The yellowing pathotype of *Fusarium oxysporum f.sp. ciceris* causes gradual leaf yellowing accompanied by vascular browning and late death, whereas the wilting pathotypeleads to rapid chlorosis, flaccidity, vascular browning and premature plant death (Singh and Vyas 2021, Younesi *et al.* 2021). The expression of Fusarium wilt in chickpea is not limited to a specific growth phase, Symptoms can emerge at any time and infected plants are often seen either in concentrated patches or dispersed across the field (Jiménez-Díaz *et al.* 2015). In susceptible chickpea varieties, wilt symptoms appear as early as 25 days after sowing, a condition termed as early wilt (Al-Taae and Al-Jobory 2013, Jiménez-Díaz *et al.* 2015). However, symptoms typically become more evident and pronounced during the early stages of flowering, about 42-54 days post-sowing, and continue to develop until pod setting (Besha 2021).

Initial yellowing symptoms of chickpea wilt appear in the lower plant sections approximately two weeks post-sowing, gradually progressing upwards. In cases of highly virulent pathogen races, yellowing intensifies around 40 days of post-sowing leading to complete plant death by 8 weeks after sowing (Younesi *et al.* 2021). However, wilt symptoms are typically more pronounced during early flowering, 42 to 54 days after sowing and can also manifest up to pod setting stage a condition termed as late wilt (Jendoubi *et al.* 2017). Late-wilted plants exhibit drooping petioles, rachis and leaflets,followed by yellowing and necrosis of the leaf (Jiménez-Díaz *et al.* 2015). Early wilting generally causes greater yield reduction than late wilting (Jendoubi *et al.* 2017). Moreover, seeds harvested from late-wilted chickpea plants are often lighter, rougher, and duller than those sourced from healthy plants (Navas-Cortes *et al.* 2000).

The fungus, *Fusarium oxysporum* f.sp. *ciceris* is specifically pathogenic to cicer species, with chickpea being the sole cultivated species affected of which chickpea is the only cultivated species. However, it can also colonize the root tissues of other grain legumes, including bean, faba bean (*Vicia faba* L.), lentil (*Lens culinaris*), field pea (*Pisum sativum* L.) and pigeon pea (*Cajanus cajans*) without inducing visible symptoms, thereby acting as symptomless carriers. Moreover, other crops and dicotyledonous weeds can also serve as symptomless carriers and alternate hosts of this pathogen (Trapero-Casas A and Jimenez-Diaz RM 1985). While *Fusarium oxysporum* f.sp. *ciceris* primarily targets chickpea, it has been observed to cause mild infection in other leguminous and non-leguminous plants like canola and lentil under specific experimental conditions (Zhou *et al.* 2021). This suggests a limited degree of host range overlap or the presence of less virulent strains capable of infecting these secondary hosts.

Distribution and disease pressure in Ethiopia

Chickpea wilt, a disease with a global presence across 32 countries and six continents (M Singh and Kumar 2014), was initially noted in India by Butler in 1918.Its etiology, however, remained a mystery until Padwick's finding in 1940 (Cunnington 2007). It is incited by the soil-borne pathogen *Fusarium* *oxysporum* f.sp. *ciceris* remains a paramount threat to global chickpea production (Sharma *et al.* 2012, Soorni *et al.* 2025).Its impact and prevalence arenot uniform, vary from one country to another. Chickpea Fusarium wilt in Ethiopia spreads to almost all chickpea-producing areas with increasing trends of its pressure and yield loss. It is reviewed that the diseaseoccursin all chickpea-producing regions of Amhara (11%-58%), Oromia (8%-17%) and Tigray (5%-31%) mean incidence rate (Bekele *et al.* 2021, Yimer *et al.* 2018).

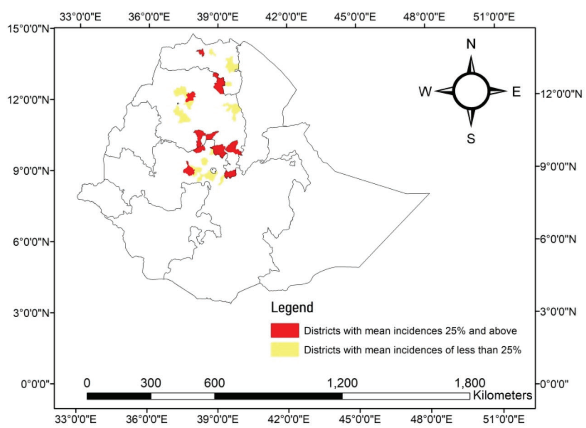

Fig. 2. Distribution and intensity of chickpea Fusarium wilt across the major chickpea-producing regions of Ethiopia. Source: (Ali and Terefe 2021, Bekele *et al.* 2021, Negash 2021, Yimer *et al.* 2018)

In Amhara, where the disease was found to be destructive, more than 65% and 60% of the surveyed districts, respectively, retained mean wilt incidence and percent severity index of above 25%. The current review revealed that the diseases were distributed to over 36 districts of the country during the study from 2008 to 2025.Thus, the maximum wilt incidence was observed from GonjiKolela (58%) in Amhara regional state, while the lowest was from Endamehoni (5%) and Becho (%) in Tigray and Oromia region, respectively. The mean incidence rate of chickpea Fusarium wilt was varied from 5% in Endamehoni to 51-58% in Gonjkolela and Enemay districts, respectively, whereas the mean percent severity index ranged between 3 to 50.29% (Yimer *et al.* 2018).

Pathogenic Variability of F. oxysporum f. sp. ciceris

The fungus *F. oxysporum* f. sp. *ciceris* exhibits pathogenic variability encompassing distinct races and pathotypes that differ in their ability to infect chickpea and the symptoms they cause (Jendoubi *et al.* 2017). Due to variation in their virulence among isolates of *Fusarium oxysporum* f. sp. *Ciceris*

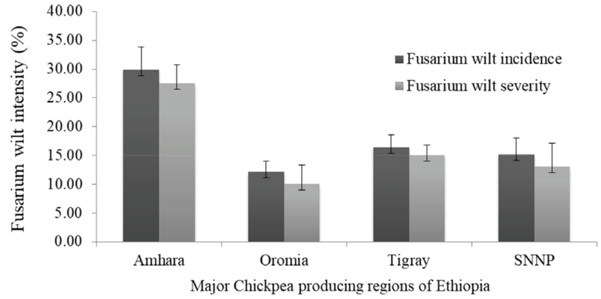

Fig. 3. Intensity of Chickpea Fusarium wilt in major chickpea growing regional states of Ethiopia (Source: Sultan Mohammed 2018, Ali and Terefe, 2021, Bekele *et al.* 2021)

they have been categorized into pathogenic races. The eight established distinct physiological races recognized globally, namely 0, 1A, 1B/C, 2, 3, 4, 5, and 6, differ in their ability to infect and cause disease on different chickpea genotypes (Jendoubi *et al.* 2017). Hossain *et al.* (2013) also disclosed that isolates of *Fusarium oxysporum* f. sp. *ciceris* resulted in an infection potential of ranged from weakly virulent to highly virulent against their origin of chickpea seed samples in pot culture based on pathogenicity test. Studies conducted in Ethiopia revealed a wider range of pathogenic variability among isolates collected from different areas.

F. oxysporum f. sp. *ciceris*, once established in the soil, the pathogen can persist for several years during this prolonged soil-borne phase. It is subjected to various environmental stresses and biological interactions, which contribute to the selection and emergence of genetic variations within the population (Besha 2021). According to Ali and Terefe (2021) also reported that samples collected from the North Shewa zone of 5 districts indicated that twenty-six isolates were identified. All isolates were highly varied in their colony color, colony texture, capacity to sporulation, shape and size of conidia, septation character, and chlamydospore types. Most of the isolates were found to be virulent and highly pathogenic, inducing ≥ 50% wilting (Ali and Terefe 2021). Further to this, the most virulent isolate exhibited a wilt incidence of 80% and 86.67%, both collected from the East Dembiya district. This was followed by isolates from Gondar Zuria district, which had a wilt incidence of 73.33%. The least virulent isolate showed a wilt incidence of only 13.33% from the Foegra district. The results indicate that *Fusarium oxysporum* f. sp. *Ciceris* isolates from East Dembia and Gondar Zuria districts were the most virulent (Yemataw *et al.* 2025a).

Table 1. Economic importance, incidence and severity of chickpea Fusarium wilt in chickpea-producing districts of Ethiopia

Districts	**Regions**	**Incidence (%)**	**PSI(%)**	**References**
Ensaro	Amhara	50.19	50.29	
Menz Mama	Amhara	37.39	38.53	
Merhabete	Amhara	47.71	48.33	(Ali and Terefe 2021)
MoretnaJiru	Amhara	43.06	43.06	
Mojanawedera	Amhara	34.27	34.27	
Gondar Zuria	Amhara	36.09	-	
East Dembia	Amhara	38.26	-	(Yemataw *et al.* 2025a)
LiboKemkem	Amhara	31.51	-	
Fogera	Amhara	32.83	-	
Enemay	Amhara	18.6-19.4	18.4-19.5	
EnarjiEnawga	Amhara	23.4-38.2	21.4-36.3	
YilmanaDensa	Amhara	18.6-23.1	18.49-21.9	(Yilma, *et al.* 2025a)
Bahir Dar Zuria	Amhara	11.7-17.93	12.7-17.1	
Fogera	Amhara	21.8-23.9	21.4-22.4	
LiboKemkem	Amhara	21.7-27.8	22.2-25.9	
GonjiKolela	Amhara	58.0	42.0	
EnarjiEnawga	Amhara	40.0	30.0	
Bahir Dar Zuria	Amhara	11.0	8.0	
Enemay	Amhara	51.0	38.0	
YilmanaDensa	Amhara	19.0	19.0	
Dejen	Amhara	25.0	26.0	
Wegde	Amhara	27.0	27.0	
Tehuledere	Amhara	10.0	10.0	(Yimer *et al.* 2018)
Lome	Oromia	14.0	11.0	
Ada'a	Oromia	16.0	12.0	
Illu	Oromia	13.0	11.0	
GerarJarso	Oromia	16.0	13.0	
WaraJarso	Oromia	17.0	17.0	
Becho	Oromia	5.0	3.0	
Sebeta	Oromia	8.0	5.0	
Gumbichu	Oromia	55.81	-	
Bora	Oromia	44.32	-	(Negash 2021)
Adea	Oromia	36.46	-	
Lume	Oromia	31.79	-	
TahtayKoraro	Tigray	31.0	32.0	
Wukro	Tigray	21.0	18.0	
Maychew	Tigray	16.0	14.0	(Yimer *et al.* 2018)
Enderta	Tigray	9.0	6.0	
Endamehoni	Tigray	5.0	5.0	
Districts	Regions	Incidence (%)	PSI(%)	References
Ensaro	Amhara	50.19	50.29	
Menz Mama	Amhara	37.39	38.53	
Merhabete	Amhara	47.71	48.33	(Ali and Terefe 2021)
MoretnaJiru	Amhara	43.06	43.06	
Mojanawedera	Amhara	34.27	34.27	
Gondar Zuria	Amhara	36.09	-	
East Dembia	Amhara	38.26	-	(Yemataw *et al.* 2025a)
LiboKemkem	Amhara	31.51	-	
Fogera	Amhara	32.83	-	
Ambo	Oromia	40.0	-	(Assfaw and Negash 2020)
Dendi	Oromia	29.1	-	
GonjiKolela	Amhara	58.0	42.0	
EnarjiEnawga	Amhara	40.0	30.0	
Bahir Dar Zuria	Amhara	11.0	8.0	
Enemay	Amhara	51.0	38.0	
YilmanaDensa	Amhara	19.0	19.0	
Dejen	Amhara	25.0	26.0	
Wegde	Amhara	27.0	27.0	
Tehuledere	Amhara	10.0	10.0	(Yimer *et al.* 2018)
Lome	Oromia	14.0	11.0	
Ada'a	Oromia	16.0	12.0	
Illu	Oromia	13.0	11.0	
GerarJarso	Oromia	16.0	13.0	
WaraJarso	Oromia	17.0	17.0	
Becho	Oromia	5.0	3.0	
Sebeta	Oromia	8.0	5.0	
Gumbichu	Oromia	55.81	-	
Bora	Oromia	44.32	-	(Negash 2021)
Adea	Oromia	36.46	-	
Lume	Oromia	31.79	-	
TahtayKoraro	Tigray	31.0	32.0	
Wukro	Tigray	21.0	18.0	
Maychew	Tigray	16.0	14.0	(Yimer *et al.* 2018)
Enderta	Tigray	9.0	6.0	
Endamehoni	Tigray	5.0	5.0	

Where PSI= percent severity index

CHICKPEA FUSARIUM WILT MANAGEMENT PRACTICES

Agronomic practices

Chickpea Fusarium wilt, characterized by a single infection known as monocyclic disease, is primarily driven by the initial pathogen inoculum. Therefore, effective management of the disease should concentrate on two key areas: implementing measures to prevent pathogen introduction and employing techniques to reduce the amount and infectivity of the existing inoculum in the field. Fusarium wilt management requires both pathogen exclusion and inoculum reduction. Various cultural management practices are employed and resulted in partial control against chickpea wilt, including manure application, adjusted sowing dates, intercropping, planting depth, and optimum spacing. According to Abera *et al.* 2011, Fusarium wilt incidence was significantly lower with green manure and dried plant residue applications, although complete disease suppression was not observed.

Chickpea intercropped with mustard efficiently decreased the disease intensity and lowered pathogen population in the soil with improved seed germination, high number of root nodules, number of pods per plant, and grain yield (Jamil *et al.* 2020). On the other hand, the study also revealed that optimizing inter-raw spacing plays a crucial role in mitigating the disease. Specifically, chickpea crops sown with a wider inter-row spacing of 40 cm exhibited a lower percentage of wilt incidence (28% to 33%) compared to those sown with a narrower 20 cm spacing, which showed a higher wilt incidence percentage (38% and 41%) (Jamil *et al.* 2020). It is also suggested that late planting and effective and on-time weed management are important agronomic practices to tackle chickpea Fusarium wilt and associated wilt root complex (Ali and Terefe 2021, Bekele *et al.* 2021, Yimer *et al.* 2018). A study conducted on the cucumber plant, Vermicompost treatment showed significant reduction in the incidence of Fusarium wilt and gave taller plant height, better stem diameter, enhanced leaf area, and ultimately increased fruit yield (Zhang *et al.* 2020). Also, (Kaur *et al.* 2023) reported application of Vermicompost alone at the rate of 5t ha^{-1} gave the maximum yield of 1679 kg ha^{-1} and harvest index of 43.88% which resulted yield benefit, 27.4% compared to the control. According to (Yadav and Garg 2015), the number of pods per plant is an important yield component determining chickpea yield, which was significantly affected by the application of Vermicompostand varied from 5.3 in the control to 19.3 in the Vermicompost treated chickpea at a rate of 20%.

Table 2. Incidence of chickpea Fusarium wilt as influenced by agronomic practices

Variables	Variable classes	Incidences (%)	References
Planting time	Early planting	27.57±2.83	(Bekele *et al.* 2021)
	Intermediate	23.43±2.46	
	Delayed planting	17.11±3.06	
Planting time	16th August	36.46[a]	(Ali and Terefe 2023)
	23th August	25.67[ab]	
	30th August	20.93[b]	
Weed Management	Weeded	34.29±2.07	(Yemataw *et al.* 2025a)
	Un weeded	41.74±2.63	
Weed density	<10 weeds m^{-2}	22.42 ± 0.52	(Yilma *et al.* 2025a)
	≥10 weeds m^{-2}	28.93 ± 1.0	
Rotational crop	Common bean	53.17±17.85	(Negash 2021)
	Lentil	49.62±21.74	
	Faba bean	46.12±21.53	
	Wheat	41.61±15.68	
	Maize	37.03±11.99	
	Tef	35.06±13.41	
Length of crop rotations	1 years	37.3 ± 0.76	(Yilma *et al.* 2025a)
	2 years	27.37 ± 0.45	
	3 years	19.21 ± 0.31	
	≥4 years	13.75 ± 0.31	

Biological Control

Fusarium wilt is a soil-borne disease, and its soil-borne nature limits the success of fungicide applications for managing the disease thus, fungicide treatment is rarely successful (Abed *et al.* 2016). Inconsistencies in biological control under diversified environmental variables have been a common impediment to soil-borne pathogens (Abed *et al.* 2016). Recognizing the importance of environmentally sound and sustainable agricultural practices, there is an increasing momentum towards transitioning the biological control methods, reducing the reliance on agrochemicals (Abdalla *et al.* 2022). The existence of many microorganisms thatcan serve as an effective means of plant disease management is found to be an important opportunity. Seed treatment with *P. fluorescens* at 6 g/kg was suppressive against *Fusarium oxysporum* with a disease incidence value of 46.05, whereas the disease incidence for the control was 74.62% (Kala *et al.* 2020). Besides, (Bekkar *et al.* 2018) depicted that chickpea seeds treated by *Trichoderma harzianum* gave the lowest disease incidence (6.33%) over the control (98.33%). Moreover, chickpea seeds inoculated with *Bacillus subtilis* showeda minimum disease severity of 1.73 in comparison with the control, which gave a mean disease severity value of 3.8 measured on the basis of a 0-4 disease severity scale (Bekkar *et al.* 2018). Despite its potential and efficacy, biological control has received limited attention or has been largely overlooked as a strategy for managing this particular chickpea disease. Five tested biological (*P. fluorescens* ,*T. asperellum, P. chlororaphis, B. subtilis* and *T. harzianum*) managements were significantly reduced the wilt incidence, among them the strain CPs3 (*Pseudomonas chlororaphis*) significantly reduced the wilt incidence compared than other bio-control agents. The treatment of CPs3 (*Pseudomonas chlororaphis*) was more effective than other bio-control agents with incidence of 14.3% followed by Pf1 (*Pseudomonas fluorescens*) with recorded 35.3% however, the incidence recorded from the control / untreated was 74.3%.

Host resistance

Developing chickpea varieties that are resistant to Fusarium wilt stands out as the most effective strategy for managing this disease in chickpea some resistant varieties include Arerti and Chefe (Assfaw et al. 2019). In the Debre Zeith area, a sick plot known for its progressive and continuous Fusarium wilt infestation was used to evaluate the resistance of various chickpea varieties against wilt/ root rot resistance (Jamil *et al*. 2020, Mengist *et al*. 2018, Subhani *et al*. 2011). The successful breeding to Fusarium wilt-resistant chickpea lines and the identification of DNA markers offer valuable tools (Sharma *et al*. 2005). It is crucial to understand that the resistance exhibited by certain varieties to chickpea Fusarium wilt may only be effective against specific races of the causal pathogen (Jiménez-Gasco *et al.* 2004). Ayana, Awoke (2019) reported that variety Dehara gave the lowest disease incidence over other tested varieties in the Northwestern part of Ethiopia. Similarly, Gebeyaw *et al*. (2024) reported that Dalota and Eshete have found to be moderately resistant to the occurrence of chickpea Fusarium wilt mean incidences of 2.7% and 2.8% respectively, over local chickpea, which expressed a mean wilt incidence of 13.5% at Adet, west Gojjam, Ethiopia. Further to this Alefe *et al.* 2022 depicted that the Mitik variety retained the minimum mean Fusarium wilt incidence (6.23%) while the local variety expressed the maximum wilt incidence of 43.6% at Lasta Lalibela district of Eastern Amhara.

Fungicides and non-conventional chemicals

Seed treatment with fungicides such as Thiram and Apron Star has been reported to provide partial protection against Fusarium wilt in chickpeas (Alefe, Betselot and Yasin 2022, Mengist *et al.* 2018). The minimum disease incidence, 6% was recorded from plots treated with 70% Thiophanate-methyl as compared to untreated plots with 80% disease incidence (Maitlo *et al.* 2014). Moreover, (Yadav *et al*. 2018) reported that out of 10 fungicides tested in the laboratory, Benlate, Companion, Bavistin, thiram and Chlorothalonil absolutely (100%) suppressed the growth of the fungus. Other fungicides like Topsin-M- M , Vitavax powder, and Indofil M-45 were also found effective to check the growth of pathogen by inhibiting 80.95%, 60.31%, and 46.91%, respectively (Yadav *et al*. 2018). Further to this, Mengist *et al.* 2018 reported that variety Shasho treated with fungicide Apron Star resulted significant reduction in chickpea Fusarium wilt incidence. Moreover, Alefe *et al.* 2022 also revealed that chickpea seeds treated with thiram and Apron Star resulted in lower wilt incidence levels at Sekota Zuria District and Lalibela District in Eastern Amhara, Ethiopia. In addition, the lowest Fusarium wilt incidence values of 19.50% and area under disease progress curve values of 524% day and high grain yield of 3.53 t ha^{-1} were recorded in the Natoli variety of chickpea treated with Apron Star fungicides. Conversely, the highest incidence (41.66%), area under disease progress curve (18.28%) per day, very low grain yield of 0.89 t ha^{-1}, respectively,were recorded from untreated earlier chickpea landraces (Yemataw *et al.* 2025b).Further to this, Bhimani 2020 reported thatCarbendazim 50% WP showed the least disease incidence of 23.33% and 76.66% yield increase over the control, which retained an incidence of 99.98%. With respect to non-conventional chemicals, wilt incidence percentage were reduced in pots sown with seed treated with Zinc chloride Calcium carbonate, Manganese sulphate and Boric acid, with wilt incidence percentage of 14.75%, 14.75% and 18.04%, respectively, whereas the untreated wilt incidence was 44.98% under greenhouse conditions (Zope *et al.* 2018).

Integrated Fusarium wilt management

Encouraging outcomes indicated that combining effective microorganism Apron Star, stubble-free field, and resistant variety created conditions suppressive to Fusarium wilt of chickpea. Furthermore, the integration of effective micro-organism, neem seed extracts and resistant variety significantly enhanced yield and its contributing components. According to Zewdie and Bedasa (2020), the chickpea variety Arerti treated with protective fungicides sown on a raised seedbed resulted in a 41.17% yield advantage as compared to the untreated Arerti variety planted on a flat seedbed. Moreover, Nandisha and Huilgol

(2021) disclosed that chickpea seed treated with Carbondazim 12% + *Curcuma longa* (turmeric) rhizome extract @150ml kg of seeds gave minimum wilt incidence (1.46%) and a maximum yield of 1037 kg ha^{-1} whereas wilt incidence of 12.73% and yield of 602 kg ha^{-1} was recorded from the control. Besides, chickpea seed treated with Mancozeb 63%@ 2g/kg of seeds combined with carbondazim 12% resulted in a yield advantage of 34.42% as compared to the control (Nandisha and Huilgol 2021). Getachew (2012) reported that employing raised bed preparation, selecting tolerant varieties, and ensuring optimum planting time were effective in managing this particular disease and reduced wilt-related mortality of chickpea stands.

Application of Trichoderma species integrated with moderately susceptible or resistant cultivars is more effective in controlling chickpea Fusarium wilt by 30-46% (Meki *et al.*, 2011). Combined treatment consisting of 15% Vermicompost, seed bacterization and pre-inoculation foliar spray of salicylic acid achieved complete suppression against *Fusarium oxysporum* f.sp. *ciceris*. Planting time and varieties significantly impacted the intensity of chickpea Fusarium wilt. Thus, variety Mastewalsowin late in the season recorded the minimum wilt incidence of 10.2% however, early planted Arerti variety expressed the maximum (50.6%) mean wilt incidence at AlemKetema, suggesting the significant contribution of combining sowing date with varieties for Fusarium wilt management (Ali and Terefe 2023). The interaction among seed dressing fungicides, chickpea varieties, and application of Vermicompost significantly reduced Fusarium wilt intensity, enhanced grain yield, and components of chickpea (Yilma *et al.* 2025b). Thus, Natoli variety treated with Goldazim 500SC seed dressing fungicide and supplemented with vermicompost showed the lowest wilt incidences (0.35%) and percent severity index (0.6%) at Fogera district. Conversely, the untreated Dehra variety retained the highest mean incidence and PSI of 27.26% and 31.07%, respectively, at Bahir Dar Zuria. The maximum grain yield recorded was 2953.8 kg ha^{-1}, achieved by the Natoli treated with Goldazim 500SC and receiving vermicompost application (Yilma *et al.* 2025b). Resistant variety integrated with fungicides caused a significant reduction of chickpea Fusarium wilt, leading to an increase in chickpea grain yield (Yemataw *et al.* 2025b).

CONCLUSION

Chickpea Fusarium wilt stands as a significant threat to chickpea production across Ethiopia's major growing regions. The disease's prevalence, indicated by varying incidence rates ranging from 5-58% and severity indices 3-42% across Amhara, Oromia, and Tigray regions, reflects its widespread impact. The data underscores the severity of the issue, particularly in areas like GonjiKolela and Enemay districts in Amhara, where incidence rates soar above 50%. The disease's impact is not uniform, displaying significant variability across different districts, highlighting the complex interplay of environmental factors, agricultural practices, and pathogen diversity. The pathogenic diversity of *Fusarium oxysporum* f. sp. *ciceris,* further complicates management efforts. Isolates exhibit varying levels of virulence and pathogenicity, affecting different chickpea varieties differently. This variability necessitates a tailored approach to disease management, considering the specific pathogen races and isolates specific to the region. Adopting a comprehensive and integrated approach incorporating resistant varieties, biological controls, delayed planting, efficient weed management, implementing cereal-based long-term crop rotation, and judicious use of fungicides can effectively mitigate the impact of this devastating disease and ensure sustainable chickpea production.

CONFLICT OF INTEREST

The authors affirm that there is no potential conflict of interest to disclose

DATA AVAILABILITY

The data supporting the findings of this work is included within the document

FUNDING STATEMENT

This work received no external funding

AUTHORS' CONTRIBUTION

The corresponding author synthesis the data, organize and write the article and all co-authors involved in language editing, and provide supplementary information for enrichment of the article.

REFERENCES

Abdalla SA, Naim AM El, Ali A, Sriwijaya U and Ibrahim E. 2022. Screening of Rhizobacterial Isolates for Biological Control of Fusarium Wilt Disease of Chickpea. World Journal of Agricultural Research **10**(2): 0–7.

Abed H, Rouag N, Mouatassem D and Rouabhi A. 2016. Screening for Pseudomonas and Bacillus antagonistic rhizobacteria strains for the biocontrol of Fusarium wilt of chickpea. Eurasian Journal of Soil Science **5**(3):182–191.

Abera M, Ahmad S, Fininsa C and Sakhuja PK. 2011. Effect of mustard green manure and dried plant residue on chickpea wilt (*Fusarium oxysporum* f . sp . *ciceris*). Archives of Phytopathology and Plant Protection **44**(9): 821–831. https://doi.org/10.1080/03235408.2010.490390.

Al-Taae AK and Al-Jobory SE. 2013. Pathogenic Variability in Isolates of *Fusarium oxysporum* f. sp. *ciceris*. Journal of University of Zakho **1**(1): 108–114.

Alefe ZE, Betselot GH and Yasin AM. 2022. Evaluations of Different Seed-Dressing Fungicides with Chickpea Varieties for the Management of Fusarium Wilt in Eastern. Advances in Agriculture, 2022: 1-6. https://doi.org/10.1155/2022/9324559

Ali B and Terefe H. 2021. Spatial distribution and characterization of Fusarium wilt (*Fusarium oxysporum* f.sp. *ciceris*) of chickpea in Northern Shoa, Ethiopia. Archives of Phytopathology and Plant Protection **54**(19–20): 1578–1602. https://doi.org/10.1080/03235408.2021.1929689.

Ali B and Terefe H. 2023. Host resistance by sowing date interaction reduced Fusarium wilt pressure and improved grain yield of chickpea (*Cicer arietinum* L.) in North Shoa, Ethiopia. Agrosystems, Geosciences and Environment **6** (3): 1–16. https://doi.org/10.1002/agg2.20400.

Alsamman AM, H. Mousa K, Istanbuli T, Abd El-Maksoud MM, Tawkaz S and Hamwieh A. 2023. Unveiling the genetic basis of Fusarium wilt resistance in chickpea using GWAS analysis and characterization of candidate genes. Frontiers in Genetics **14**: 1–11. https://doi.org/10.3389/fgene.2023.1292009.

Asnake F and Degefu T. 2019. A Guide to Accelerated Breeding Cycle in Chickpea to Enhance Rate of Gain A Guide to Accelerated Breeding Cycle in Chickpea to Enhance Rate of Gain. Technical Manual No. 1/2019. ICRISAT, Adis Ababa, Euthopia. Pp. 22.

Assfaw D and Negash T. 2020. Spatial Distribution and Association of Chickpea Wilt / Root Rots Epidemics with Biophysical Factors at West Shewa , Oromia Regional State , Ethiopia Plant Pathology & Microbiology. Journal of Plant Pathology and Microbiology **11**(9): 7–12.https://doi.org/10.35248/2157-7471.20.11.513.

Assfaw D, Selvara T and Gezahegn Getaneh. 2019. Pathogen Identification and Evaluation of Chickpea Varieties for Resistance Against the Pathogens in West Shewa, Oromia Regional State, Ethiopia. Advances in Life Science and Technology **73**: 29–42. https://doi.org/10.7176/ALST.

Ayana, Awoke NH and WT. 2019. Screening Desi and Kabuli Chick Pea Varieties against Fusarium Wilt Plant Pathology & Microbiology Screening Desi and Kabuli Chick Pea Varieties against Fusarium Wilt Resistance in West Gojam , Northwestern Ethiopia. Journal of Plant Pathology & Microbiology **10**(2). https://doi.org/10.4172/2157-7471.1000474.

Bekele D, Tesfaye K, Fikre A and Cook DR. 2021. The extent and association of chickpea Fusarium wilt and root rot disease pressure with major biophysical factors in Ethiopia. Journal of Plant Pathology **103**(2): 409–419. https://doi.org/10.1007/s42161-021-00779-4.

Bekkar AA, Zaim S and Belabid L. 2018. Archives of Phytopathology and Plant Protection Induction of systemic resistance in chickpea against Fusarium wilt by Bacillus strains. Archives of Phytopathology and Plant Protection **5408**: 1–11. https://doi.org/10.1080/03235408.2018.1438819.

Besha DB. 2021. Mapping of Novel Quantitative Trait Loci (QTL) for Fusarium Wilt Resistance in Chickpea (*Cicer arietinum* L.) and Analysis of the Genomic Diversity of Fusarium oxysporum f. sp. ciceris in Ethiopia, Addis ababa university, institute of biotechnology, PhD Dissertation. Pp. 218

Bhimani M. 2020. Efficacy of different fungicides for the management of chickpea wilt (Fusarium Efficacy of different fungicides for the management of chickpea wilt (*Fusarium oxysporum* f.sp. *ciceri*). International Journal of Chemical Studies **6**(2): 199-205. https://doi.org/10.13140/RG.2.2.32521.88160.

Charitha N, Paslawar AN and Darekar NK. 2025. Chickpea Thrive : Unleashing Potential in Intercropping Systems with Different Organic and Natural Farming Practices. **48**(9): 1547–1552. 10.18805/LR-5517

CSA. 2021. Report on crop and livestock product utilization (Private peasant holdings Meher season). Volume VII. Statistical Bulletin 588. *Volume VII Report* **2**(January 2021): 156.

Dubey SC, Singh SR and Singh B. 2010. Morphological and pathogenic variability of Indian isolates of *Fusarium oxysporum* f. sp. *ciceris* causing chickpea wilt. Archives of Phytopathology and Plant Protection **43**(2): 174–190. https://doi.org/10.1080/03235400802021108

FAOSTAT. 2020. Available online: https://www.fao.org/faostat/en/#data (accessed on 23 August 2024).

Fikre A and Bekele D. 2020. Chickpea breeding and crop improvement in Ethiopia: Past, present and the future. Universal Journal of Agricultural Research **8**(2):33–40. https://doi.org/10.13189/ujar.2020.080202.

Fikre A, Desmae H and Ahmed S. 2020. Tapping the Economic Potential of Chickpea in. MDPI Agronomy **10**:1-22

Gebeyaw M, Fikre A, Abate A and Alemu T. 2024. Participatory variety evaluation and selection of chickpea (*Cicer arietinum* L.) varieties; an underpinning to novel technology uptake in northwestern Ethiopia. Heliyon **10**(8):e29801. https://doi.org/10.1016/j.heliyon.2024.e29801

Getachew A. 2012. Influence of chickpea fusarium wilts (*Fusarium oxysporum* f. sp. ciceris) on Desi and Kabuli-type of chickpea in integrated disease management option at wilt sick plot in north western Ethiopia. International Journal of Current Research **4**(04): 46-052.

Girma N, Fikre A and Ojiewo CO. 2017. The Genotypic and Phenotypic Basis of Chickpea (*Cicer arietinum* L.) Cultivars for Irrigation-Based Production in Ethiopia. Journal of Agricultural Science **9**(8): 229. https://doi.org/10.5539/jas.v9n8p229.

Gizaw B, ZerihunTsegay, Genene Tefera, Endegena Aynalem EA and GA. 2018. Traditional Knowledge on Teff (*Eragrostis tef)* Farming Practice and Role of Crop Rotation to Enrich Plant Growth Promoting Microbes for Soil Fertility in East Showa: Ethiopia. Agricultural Research & Technology: Open Access Journal **16**(5): 139–155.10.19080/ARTOAJ.2018.16.556001

Hailemichael F. 2020. Characterizing the Effectiveness of Nitrogen Fixing Bacteria to Optimize Chickpea (*Cicer arietinum* L) Production. International Journal of Research Studies in Science, Engineering and Technology 7(11): 23–34.

Hossain M, Hossain N, Sultana F, Mohammad S and Islam N. 2013. Integrated management of Fusarium wilt of chickpea (*Cicer arietinum* L .) caused by *Fusarium oxysporum* f . sp . *ciceris* with microbial antagonist , botanical extract and fungicide. African Journal of Biotechnology **12**(29): 4699–4706.https://doi.org/10.5897/AJB2013.12503.

Jamil A, Ashraf S and Jamil A. 2020. Archives of Phytopathology and Plant Protection Utilization of chemical fungicides in managing the wilt disease of chickpea caused by *Fusarium oxysporum* f.sp. *ciceri*. Archives of Phytopathology and Plant Protection **0**(0): 1–23. https://doi.org/10.1080/03235408.2020.1803705.

Jemberu T, Fikre A, Abeje Y, Tebabal B, Worku Y and Jorgi T. 2018. Agronomic and Economic Evaluation of Wheat-Chickpea Double Cropping on the Vertisol of Takusa, North Western Ethiopia. Ethiopian Journal of Crop Science **6**(2): 67–78.

Jendoubi W, Bouhadida M, Boukteb A, Béji M and Kharrat M. 2017. Fusarium wilt affecting chickpea crop. Agriculture (Switzerland) **7**(3): 1–16. https://doi.org/10.3390/agriculture7030023.

Jiménez-Díaz RM, Castillo P, Jiménez-Gasco M del M, Landa BB and Navas-Cortés JA. 2015. Fusarium wilt of chickpeas: Biology, ecology and management. Crop Protection **73**: 16–27.

Jiménez-Gasco MDM, Milgroom MG and Jiménez-Díaz RM. 2004. Stepwise evolution of races in *Fusarium oxysporum* f. sp. ciceris inferred from fingerprinting with repetitive DNA sequences. Phytopathology **94**(3): 228–235. https://doi.org/10.1094/phyto.2004.94.3.228.

Kala C, Gangopadhyay S and Godara S L. 2020. Eco-friendly management of wilt caused by *Fusarium oxysporum* f. sp. *ciceri* in chickpea Eco-friendly management of wilt caused by *Fusarium oxysporum* f . sp . *Ciceri* in chickpea. Legume Research **39**(1): 129-134. https://doi.org/10.18805/lr.v0iOF.6789.

Kaur G, *Kumar* A and Singh R. 2023. Effect of Vermicompost , Biofertilizers and in Organic Fertilizers on Nutrient Uptake and Physico-chemical Properties of Soil : A Case Study of Chickpea (*Cicer arietinum* L .). International Journal of Environment and Climate Change **13**(10): 4519–4525. https://doi.org/10.9734/IJECC/2023/v13i103130.

Keneni G, Bekele E, Imtiaz M, Dagne K, Getu E and Assefa F. 2012. Genetic Diversity and Population Structure of Ethiopian Chickpea (*Cicer arietinum* L.) Germplasm Accessions from Different Geographical Origins as Revealed by Microsatellite Markers. Plant Molecular Biology Reporter **30**(3): 654–665. https://doi.org/10.1007/s11105-011-0374-6.

Nandeesha KL and Huilgol SN. 2021. In vitro evaluation of fungicides against *Fusarium oxysporum* f . sp. ciceri. The Pharma Innovation Journal **10**(7): 181-184

Korbu L, Fikre A, Tesfaye K, Funga A, Bekele D and Ojiewo CO. 2022. Response of chickpea to varying moisture stress conditions in Ethiopia. Agrosystems, Geosciences and Environment **5**(1): 1–18. https://doi.org/10.1002/agg2.20234.

Korbu L, Tafes B, Kassa G, Mola T and Fikre A. 2020. Unlocking the genetic potential of chickpea through improved crop management practices in Ethiopia. A review. Agronomy for Sustainable Development **40(**13): 1-20. https://doi.org/10.1007/s13593-020-00618-3.

Kumar S, Gopinath KA, Sheoran S, Meena RS, Srinivasarao C, Bedwal S, Jangir CK, Mrunalini K, Jat R and Praharaj CS. 2023. Pulse-based cropping systems for soil health restoration, resources conservation, and nutritional and environmental security in rainfed agroecosystems. Frontiers in Microbiology **13**:1-29. https://doi.org/10.3389/fmicb.2022.1041124.

Maitlo SA, Syed RN, Rustamani MA, Khuhro RD and Lodhi AM. 2014. Comparative efficacy of different fungicides against fusarium wilt of chickpea (*Cicer arietinum* L.). Pakistan Journal of Botani **46**(6): 2305–2312.

Meki S, Ahmed S, Sakhuja PK, Berhan D, Gene I, Program M and Dawa D. 2008. Archives Of Phytopathology And Plant Protection Control of chickpea wilt (*Fusarium oxysporum* f. sp. *ciceris*) using Trichoderma spp. in Ethiopia. Archives of Phytopathology and Plant Protection (January 2015): 37–41. https://doi.org/10.1080/03235400903093071.

Mengist Y, Sahile S, Sintayehu A and Singh S. 2018. Evaluation of Chickpea Varieties and Fungicides for the Management of Chickpea Fusarium Wilt Disease (*Fusarium oxysporum* f. sp. *ciceris*) at Adet Sick Plot in Northwest Ethiopia. International Journal of Agronomy, https://doi.org/10.1155/2018/6015205

Merga B and Haji J. 2019. Economic importance of chickpea: Production, value, and world trade. Cogent Food and Agriculture **5**(1):1-12. https://doi.org/10.1080/23311932.2019.1615718.

Mulat A, Giziew A and Ayalew D. 2022. Heliyon Analyzing constraints of smallholders' chickpea (*Cicer arietinum* L.) production systems in Gondar Zuria Woreda of Ethiopia using the Henry Garrett's ranking technique. Heliyon **8**(October): e11126. https://doi.org/10.1016/j.heliyon.2022.e11126.

Nasr Esfahani M, Sulieman S, Schulze J, Yamaguchi-Shinozaki K, Shinozaki K and Tran LS P. 2014. Mechanisms of physiological adjustment of N2 fixation in Cicer arietinum L. (chickpea) during early stages of water deficit: Single or multi-factor controls. Plant Journal **79**(6): 964–980. https://doi.org/10.1111/tpj.12599.

Navas-Cortes JA, Hau B and Jimenez-Diaz RM. 2000. Yield loss in chickpeas in relation to development of Fusarium wilt epidemics. Phytopathology **90**(11):1269–1278. https://doi.org/10.1094/PHYTO.2000.90.11.1269.

Negash E. 2021. Distribution of Fusarium Wilt of Chickpea and its Association with Biophysical Factors in East Shewa Zone, Central Ethiopia. Pest Management Journal of Ethiopia **24**(1): 68-81.

Patra S and Kumar Biswas M. 2017. Studies On Cultural, Morphological And Pathogenic Variability Among The Isolates of *Fusarium oxysporum* f. sp. *ciceri* Causing Wilt Of Chickpea In vitro Evaluation of Bio-control Agents against Alternaria brassicae View project. International Journal of Plant, Animal and Environmental Sciences International Journal of Food Science **7**(1): 11-16. https://doi.org/10.21276/Ijpaes.

Pooniya V, Zhiipao RR, Biswakarma N, Jat SL, Kumar D and Parihar CM. 2021. Long - term conservation agriculture and best nutrient management improves productivity and profitability coupled with soil properties of a maize – chickpea rotation. Scientific Reports 1–13. https://doi.org/10.1038/s41598-021-89737-9.

Richards MF, Maphosa L and Preston AL. 2022. Impact of Sowing Time on Chickpea (*Cicer arietinum* L.) Biomass Accumulation and Yield. Agronomy **12**(1), 160160. https://doi.org/10.3390/agronomy12010160.

Rocha FS, Sharma M, Tarafdar A, Chen W, Azevedo DMQ, Castillo P, Costa CA and Chobe DR. 2024. Diseases of Chickpea. In: Elmer, W.H., McGrath, M., McGovern, R.J. (eds) Handbook of Vegetable and Herb Diseases. Handbook of Plant Disease Management. Springer, Cham. https://doi.org/10.1007/978-3-030-35512-8_26-1.

Rubyogo JC, Akpo E, Omoigui L, Pooran G, Chaturvedi SK, Fikre A, Haile D, Hakeem A, Monyo E, Nkalubo S, Fenta B, Binagwa P, Kilango M, Williams M, Mponda O, Okello D, Chichaybelu M, Miningou A, Bationo J, Sako D, Kouyate Z, Diallo S, Oteng-Frimpong R, Yirzagla J, Iorlamen T, Garba U, Mohammed H, Ojiewo C, Kamara A, Varshney R, Nigam S N, Janila P, Nadaf H L and Kalemera S. 2019. Market-led options to scale up legume seeds in developing countries: Experiences from the Tropical Legumes Project. Plant Breeding **138**(4): 474–486. https://doi.org/10.1111/pbr.12732.

Sharma KD, Chen W and Muehlbauer FJ. 2005. Genetics of chickpea resistance to five races of fusarium wilt and a concise set of race differentials for Fusarium oxysporum f. sp. ciceris. Plant Disease **89**(4): 385–390. https://doi.org/10.1094/PD-89-0385.

Sharma M, Kiran Babu T, Gaur PM, Ghosh R, Rameshwar T, Chaudhary RG, Upadhyay JP, Gupta O, Saxena DR, Kaur L, Dubey SC, Anandani VP, Harer PN, Rathore A and Pande S. 2012. Identification and multi-environment validation of resistance to *Fusarium oxysporum* f. sp. *ciceris* in chickpea. Field Crops Research **135**: 82–88. https://doi.org/10.1016/j.fcr.2012.07.004.

Shevkani K, Singh N, Chen Y, Kaur A and Yu L. 2019. Pulse proteins: secondary structure, functionality and applications. Journal of Food Science and Technology. https://doi.org/10.1007/s13197-019-03723-8.

Singh C and Vyas D. 2021. The Trends in the Evaluation of Fusarium Wilt of Chickpea. Diagnostics of Plant Diseases. https://doi.org/10.5772/intechopen.95612.

Singh M and Kumar S. 2014. Broadening the genetic base of grain cereals. Broadening the Genetic Base of Grain Cereals 1–275. https://doi.org/10.1007/978-81-322-3613-9.

Soorni J, Pourhang L, Amirbakhtiar N, Daryani P, Loni F, Pouralibaba HR, Khoshro HH, Shobbar Z and Ramandi HD. 2025. Developing resistance to Fusarium wilt in chickpea : From identifying meta-QTLs to molecular breeding. The Plant Genome 1–19. https://doi.org/10.1002/tpg2.70004.

Subhani M N, Sahi S T, Hussain S and Ali A. 2011. Evaluation of various fungicides for the control of gram wilt caused by *Fusarium oxysporium* f. sp. *ciceris*. African Journal of Agricultural Research **6**(19): 4555–4559.https://doi.org/10.5897/AJAR11.767.

Tabe-Ojong MPJ and Mausch K. 2017. Impacts of Improved Chickpea Adoption on Smallholder Production and Commercialization in Ethiopia. Future Agriculture 2017, 1–4.

Trapero-Casas A and Jimenez-Diaz RM. 1985. Fungal wilt and root rot diseases of chickpea in southern Spain. Phytopathology **75**(10): 1146-1151.

Varshney RK, Thudi M, Nayak SN, Gaur PM, Kashiwagi J, Krishnamurthy L, Jaganathan D, Koppolu J, Bohra A, Tripathi S, Rathore A, Jukanti AK, Jayalakshmi V, Vemula A, Singh SJ, Yasin M, Sheshshayee MS and Viswanatha KP. 2014. Genetic dissection of drought tolerance in chickpea (*Cicer arietinum* L.). Theoretical and Applied Genetics **127**(2): 445–462.https://doi.org/10.1007/s00122-013-2230-6.

Venkataramanamma K, Bhaskara Reddy BV, jayalakshmi RS, Jayalakshmi V and Prasad K VH. 2023. Publisher Correction: Integrated disease management of Fusarium wilt (*Fusarium oxysporum* f.sp. *ciceris*) of chickpea. Indian Phytopathology **76**(3): 955–957. https://doi.org/10.1007/s42360-023-00638-5.

Verkaart S, Munyua BG, Mausch K and Michler JD. 2017. Welfare impacts of improved chickpea adoption: A pathway for rural development in Ethiopia? Food Policy **66**: 50–61. https://doi.org/10.1016/j.foodpol.2016.11.007.

Yadav A and Garg VK. 2015. Influence of vermi-fortification on chickpea (*Cicer arietinum* L.) growth and photosynthetic pigments. International Journal of Recycling of Organic Waste in Agriculture **4**(4): 299–305. https://doi.org/10.1007/s40093-015-0109-z.

Yadav AS, Yadav S and Singh R. 2018. Screening of fungicides in vitro and seed treatment against fusarium wilt of chickpea caused by *Fusarium oxysporum* f.sp. *ciceris*. Journal of Pharmacognosy and Phytochemistry **7**(3): 2908-2911

Yemataw A, Sintayehu A, Terefe H and Abera M. 2025. Analysis of the distribution status of chickpea Fusarium wilt (*Fusarium oxysporum* f.sp. *ciceri*) and association of factors influencing the disease in Central and South Gondar, Northwestern Ethiopia. Archives of Phytopathology and Plant Protection, 1-21. https://doi.org/10.1080/03235408.2025.2489137

Yemataw A, Sintayehu A, Terefe H and Abera M. 2025. Evaluation of fungicides on the management of Fusarium wilts (*Fusarium oxysporum* f. sp. *ciceri*) diseases of chickpea varieties in Gondar Zuria district, Northwestern Ethiopia. Journal of Plant Pathology 1-8. *https://doi.org/10.1007/s42161-025-01909-y*

Yilma A, Admassu MA, Bekele FB and Alemu T. 2025. Chickpea Fusarium Wilt (*Fusarium oxysporum* f.sp. *ciceris*): Current status and biophysical factors influencing its epidemics in western Amhara , Ethiopia. CABI Agriculture and Bioscience 1–12. https://doi.org/10.1079/ab.2025.0079

Yilma A, Abera M, Bekele B, Alemu T and Vetukuri RR. 2025. Synergistic effect of seed dressing fungicides, vermicompost application and varieties on Fusarium wilt intensity, yield and yield components of chickpea (*Cicer arietinum* L.). CABI Agriculture and Bioscience **6**:1–13. https://doi.org/10.1079/ab.2025.0076

Yimer SM, Ahmed S, Fininsa C, Tadesse N, Hamwieh A and Cook DR. 2018. Distribution and factors influencing chickpea wilt and root rot epidemics in Ethiopia. Crop Protection **106**: 150–155. https://doi.org/10.1016/j.cropro.2017.12.027.

Younesi H, Darvishnia M, Bazgir E and Chehri K. 2021. Morphological, molecular and pathogenic characterization of Fusarium spp. associated with chickpea wilt in western Iran. Journal of Plant Protection Research **61**(4): 402–413. https://doi.org/10.24425/jppr.2021.139250.

Zewdie A and Bedasa T. 2020. Source of resistance to chickpea Fusarium wilt (*Fusarium oxysporum* f.sp. *ciceris*) under field conditions in Ethiopia. African Journal of Agricultural Research **15**(1):85-89.https://doi.org/10.5897/AJAR2019.14595.

Zhang X, Sa R, Gao J, Wang C, Liu D and Zhang Y. 2020. Preventive effect of vermicompost against cucumber fusarium wilt and improvement of cucumber growth and soil properties. International Journal of Agriculture and Biology **23**(3): 515-521. https://doi.org/10.17957/IJAB/15.1316.

Zhou Q, Yang Y, Wang Y, Jones C and Feindel D. 2021. Phylogenetic, phenotypic and host range characterization of five Fusarium species isolated from chickpea in Disease reports and disease diagnostics / Rapports des maladies Phylogenetic , phenotypic and host range characterization of five Fusarium species. Canadian Journal of Plant Pathology **43**(5): 651-657. https://doi.org/10.1080/07060661.2020.1869830

Zope AV, Rakhonde OS and Awadhiya GK. 2018. Efficacy of Different Non Conventional Chemicals on Incidence of Chickpea Wilt Complex Under Glass House Condition. International Journal of Research and Innovations in Earth Science **4**(6): 87-88.