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Effects of *Fusarium* wilt on chickpea in India: A review

Snehal N Dhawale[1], D A Dhale[2*]

[1] Department of Botany, Matoshri Subhadrabai Patil Arts, Science, and Late Pandurang Thakare Commerce College, Dhamni Manora, Maharashtra India

[2] Post-Graduate Department of Botany, SSVPS's, L.K. Dr. P. R. Ghogrey Science College, Dhule, Maharashtra India

Abstract

Chickpea (*Cicer arientinum* L.) is an important consumed rabbi pulse crop all over India. Wilt is caused due to *Fusarium oxysporum f.* sp. *ciceris.* It is the most severe and expansive disease of chickpea under favorable and agro-climatic conditions. It is responsible for 80 to 100% yield loss. This parasite spreads everywhere on the pieces of the tainted plant remembering seeds with extraordinary financial loss of yield for chickpea. The microbe has incredible varieties in social characters and tainting nature. Various accounts on wilt (*Fusarium*) are assessed to decide the current status of information on the illness and to discover the spaces of exploration which need moment consideration. This review focuses on accessible information on *Fusarium* wilt sickness, etiology, pathology, and impact on yield in the Indian region and also safe components adjusted by chickpea to oppose the *Fusarium* wilt.

Keywords: *Cicer arietinum*, *Fusarium oxysporum* f. sp. *ciceris*, Resistance, Wilt.

Introduction

Chickpea (*Cicer arientinum* L., Fabaceae) is a significant annual legume crop. It self-pollinated and characterized by 2n = 16. It is one of the primitive crops of the world that originated in south-eastern Turkey about 8000-9000 years ago from its wild ancestor *C. reticulatus* [33, 59]. All over the world, *C. arietinum* L. (Chickpea) is the most preferred food for vegetarians after *Phaseolus vulgaris* L. (Soya bean) and *Pisum sativum* L.(Dry bean) [14]. It stands for the third position concerning the area under cultivation [13, 37]. In the Indian subcontinent, it grows as a post-monsoon winter-season crop. It matures within 80 - 170 days. It requires 21 - 29°C nights and 18 - 26°C day's temperatures with 600 to 1000mm rainfall as an optimum condition for better growth [38, 15].

Different abiotic and biotic agents affect adversely chickpea productivity around the world [70, 13]. Chickpea is very sensitive to biotic stresses from a variety of organisms such as fungus, bacteria, viruses, mycoplasma, and nematodes. Worldwide around 172 infectious pathogens have been recorded which harmful to Chickpea [47]. A few of them are fungal species that are hazardous since they produce mycotoxins. It is, therefore, important to check to spread infection [61]. The wilt disease is found worldwide encompassing the countries such as India, Burma, Bangladesh, Chile, Ethiopia, Iran, Mexico, Nepal, Pakistan, Sudan, Syria, Tunisia, Iran, USSR Malawi, the United States, Spain, Peru, Turkey, and Italy. However, the cultivation of Chickpea is highly threatened due to this wilt disease in India, Myanmar, Nepal, Iran, Spain, Pakistan, and Tunisia. *Fusarium* wilt has been found disastrous fungal disease showing adverse effects on chickpea productivity [24, 27].

Fusarium wilt brought about by *Fusarium oxysporum f.* sp *ciceris* is the main far and wide sickness of chickpea that happen in the semi-bone-dry tropical district of the world where the chickpea developing season is much dry and warm. In Indian Sub-landmass Fusarium wilt was accounted for interestingly by Buttler in 1918 [29]. *Fusarium* wilt is a root-occupying, soil-borne organism [27, 50].

No unequivocal information is accessible regarding trim misfortunes. Nonetheless, best guesses demonstrate that misfortunes may around 10-15% every year as an ordinary component. In the long periods of extreme pestilences, crop misfortunes have shoot up as high as 60-70%. At the seedling and blossoming stage, loss of yield was 59% and 41% individually [55]. Seeds gathered from wilt-infected plants indicate low weightage, more bluntness, and wrinkled than from normal plants. The yield misfortunes fluctuate somewhere in the range of 10% and 100% relying upon the agroclimatic conditions. In India, yearly yield misfortunes because of *Fusarium* wilt were assessed about 10% [7] Chickpea sicknesses may cause yield misfortunes of up to 100% contingent upon the season of disease[48].

Fusarium wilt fundamentally diminishes both the yield and weight of chickpea. These impacts were identified with chickpea cultivar, planting date, and destructiveness of the far-reaching *F. oxysporum f.* sp. *Ciceris* [41].

The objective of this review is (i) to check event and appropriation of chickpea wilt in Indian 'Desi' cultivars (ii) to discover the seriousness of sickness and impact of agro-climatic components like soil, temperature assists with causing Fusarium in chickpea its belongings (iii) to study the pathogenesis because of *Fusarium* wilt in chickpea and normal protection component in having a plant.

1. Scientific categorization and intricacy of *Fusarium*

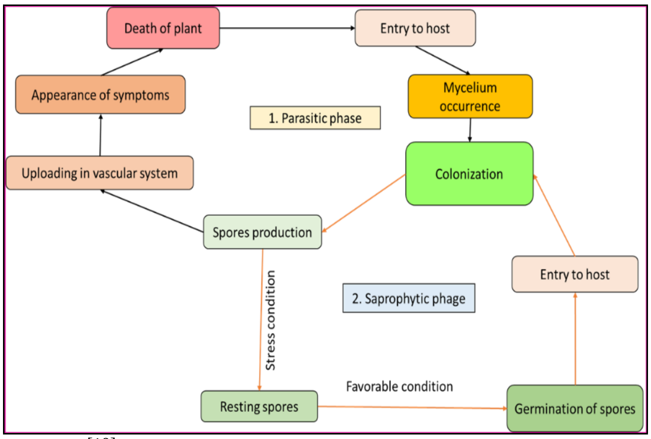
Dependent on the plant species and plant cultivars tainted, *F. oxysporum* is characterized into more than 120 structures a speciales [5]. As of now acknowledged arrangement for the *Fusarium* wilt microbe *Fusarium oxysporum* f. sp. *ciceri* is, class: Deuteromycota (Growths Defective), request:

Moniliales, family: Tuberculariaceae, sort: *Fusarium*, species: *oxysporum*, specialis: *ciceri*.

F. oxysporum f sp. *ciceris* is accounted for from the vast majority of the chickpea developing regions. *F. oxysporum* is a pathogenic organism regularly found throughout the planet. It is a dirt form ascomycete causing *Fusarium shrivel*, on numerous monetarily significant yields. The microorganism comprises more than 120 known strains and every one of which is explicit to one-of-a a kind host plant in which it causes sickness. *F. oxysporum* strains taint and slaughters numerous industrially reaped yields and vegetables. The spores of *F. oxysporum* get by in a lethargic stage in the dirt for quite a while and are effectively spread in water, it can taint vegetative cuttings and can communicate to others. Researchers throughout the planet proposed creating *F. oxysporum* as an all-inclusive model for the comprehension of parasitic destructiveness [56].

2. Advancement of *Fusarium* wilt in chickpea

History and Pathogenicity: The attack on chickpea by *Fusarium* wilt is brought by *F. oxysporum f.* sp. *ciceris* (Padwick) Matuo and K. Sato. This organism was initially named *F. orthoceras* Appel and Wollenw var. *ciceri* by Padwick; then named *F. oxysporum* Schl. *f.* sp. *ciceris* (Padwick) Snyder and Hansen by Chattopadhyay and Sen Gupta. This was recognized as the correct title of the organism until corrected by Holliday (1980) [28, 46]. This growth is pathogenic just on *Cicer* sp. on which chickpea has the solitary developed species [31]. In any case, *F. oxysporum f.* sp. *ciceris* can likewise attack root tissues of other grain vegetables like the bean, lentil (Focal point culinaris), faba bean (*Vicia faba*), pigeon pea (*Cajanus cajans*), and pea (*Pisum sativum*)[25]. *F. oxysporum f.* sp. *ciceris* shows broad pathogenic changeability notwithstanding. Two pathotypes have been recognized based on the particular yellowing or withering maladies with gritty colored vascular stains that they cause in powerless chickpeas.



(Source: [10]

Fig 1: Parasitic and sporophytic stage of *F. oxysporum f.* sp. *ciceris*

3. Sickness stages making contamination chickpea

a. Easygoing creature: To recognize the causal living being *F. oxysporum* f sp. *ciceris* applying atomic apparatuses like PCR procedures, explicit ground works, and PCR examines have been created [12, 30, 20, 23, 11]. Sickness can happen in practically all phases of plant development and infected plants might be found in gatherings or patches across the fields[46, 22, 29]. Wilting in chickpeas can be observed 20-25 days after planting. Under field conditions, the disease manifests itself during the seedling (September-October) and regenerating stages (February-Walk) of the crop.

b. Indications: Toward the beginning illness side effects show up on upper leaves, blossoms and twigs hanging, loss of bloat and staining of leaves followed by yellowing and drying of influenced plant parts may happen while in later stages it brings about the breakdown of the entire plant [34, 39].

Organisms pass in taproots, then, at that point into the vascular pack bringing about histological modification of vascular tissue and tanish staining of xylem vessel resemble. Soon, sidelong roots get dry, shriveling can be seen in upper plant parts, and in the long run entire plant is tumble off. Wilting may likewise be halfway; influencing some plant parts. Seeds in wilted plants are sub-par in quality generally more modest in size, stained, and wrinkled.

4. Occurrence of wilt on chickpea in different parts of India

Fusarium wilt is the most common disease that affects all chickpea growing areas in India. *Fusarium* wilt infection was found to be a major chickpea illness in central and southern India (Ghosh *et al.*, 2013) [21]. Chickpea is one of the most vulnerable crops to pest and disease assault, resulting in massive production losses. Chickpea wilt is a serious concern in rainfed parts of Jammu and Kashmir [1]. The Major States affected by *Fusarium* wilt: Uttar Pradesh, Madhya Pradesh, Maharashtra, Karnataka, Andra Pradesh, Chattisgarh, Jammu region [21, 1, 57].

5. Planting time and Effect of *Fusarium*

The planting period is an important component in calculating chickpea crop production. Chickpeas are traditionally sown in the Mediterranean region in the spring, though winter planting started to coordinate different edit formative stages with the greatest natural circumstance and raises net surrender by superior application of water from the soil [40]. In India Chickpea is planted from September to November and that is why it comes under the grouping of rabbi crops.

The yield of chickpea is evaluated by the time of planting; if sowing is delayed, the yield will be reduced since sowing occurs from early winter to early spring. Net abdicate diminishes caused by the infection were bigger than decreases in hundred seed weight. As a result, the normal abdicate misfortune initiated by the contamination can be credited for the most part to a drop within the number of grains per plant to a lesser degree, to a diminish in normal seed weight [41]. In India, abdicate decrease in 'Desi' assortments planted within the early October was influenced by development organize at which the contamination created due to *Fusarium* wilt. However, there is no relationship to demonstrated in-between disease development and yield loss [44].

While some researchers reported the adverse impact of intensity of disease and seed yield in *Fusarium* wilt while planting delayed up to the mid of October [28].

6. Improvement of *Fusarium* wilt in chickpea because of ecological variables

Fusarium wilt is a genuine illness danger, particularly in low precipitation regions, where climate conditions are positive for infection improvement. Brimming with air change is the reason for languishing over-farming. Environment influences plants as well as influences the microorganisms, creepy crawly bugs, or weeds that decrease yield [3]. The exemplary infection triangle distinguishes the part of the environment in sickness advancement on crops, as no destructive microbe can prompt illness on a profoundly powerless host if climatic conditions are unfavorable[2,74]. Wilt occurrence in chickpea is likewise relying upon climatic states of the locale. Data on the impact of Indian tropical climatic conditions on *Fusarium* wilt rate in chickpea is immensely restricted.

Table 1: The appearance of chickpea sickness comparable to different ecological factors in India, 2010

Parameter	Disease appearance (%)			
	AP FW	MP FW	CG FW	KS FW
Cultivar type				
Local	18.76	19.44	20.02	15.10
Improved	9.86	0.00	0.00	8.78
Soil type				
Black	14.31	19.44	19.58	11.94
Red	-	0.00	20.67	19.83
Seed treatment				
Yes	10.46	0.00	0.00	12.40
No	16.81	19.44	20.02	14.86

Source of the table: [21]

*FW: *Fusarium* wilt; AP: Andhra Pradesh; MP: Madhya Pradesh; CG: Chhattisgarh; KS: Karnataka; "-" indicate red soil type fields were not available.

7. Agro-climatic zone shrewd *Fusarium* wilt infection event on chickpea

[57] give details that, the date introduced in Fig.3 uncovered that chickpea wilt illness event was discovered greatest in moderate precipitation zone (29.28 and 30.60 %) trailed by guaranteed precipitation zone (25.12 and 26.18 %) separately, during Rabi 2018-19 and 2019-20. Nonetheless, the least infection event was recorded in the Shortage zone (19.36 and 22.11 %) during two Rabi years i.e. 2018-20 [57].

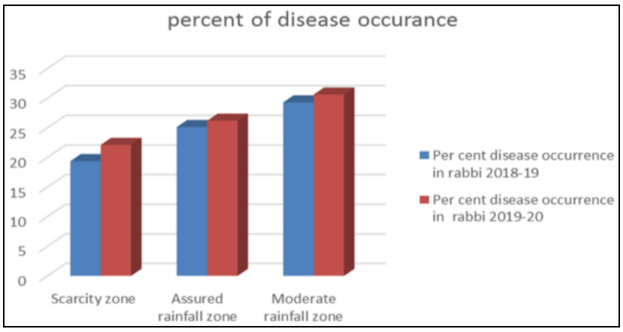


Fig 2: Agro-climatic zone shrewd *Fusarium* wilt infection event on chickpea [57].

8. Safe system of Chickpea against *Fusarium* wilt

a. Allelopathy-arrival of synthetics for protection instrument: Different frameworks can be related with the natural control of Fusarium shrink sicknesses by non-host *F. oxysporum* isolates. These components join the saprophytic challenge for supplements; parasitic contention for malady districts; and activated or made strides hindrance interior the host plant [53, 2, 36]. These systems are not restricted to each other, and a few instruments might be liable for sickness obliteration by numerous biocontrol specialists [35]. In past examinations, it was shown that specific plant protection reactions, in particular phytoalexin union and amassing of chitinase plus b-1, 3-glucanase exercises, might be engaged with the non-host opposition of chickpea against nonhost *F. oxysporum* segregates[4, 9]. Chickpea phytoalexins (the pterocarpans maackiain and medicarpin) are essential segments of the opposition system of the chickpea plant to *F. wilt* [58].

b. Biochemical changes in opposition system: Pathogenic assault on plants seems to cause changes in protein (chemical) amalgamation in the plant that can prompt the advancement of nearby obstruction or invulnerable layer around contamination destinations. Obstruction or resistance of plants to a microbe may rely upon the speed and degree of protein amalgamation instigated in the host by the microorganism. After disease, an amalgamation of pathogenesis-related protein [60]. The host-microbe collaboration is extremely intricate and assorted. Opposition in higher plants against microbial microorganisms is the consequence of constitutive and inducible guard components. The metabolic changes happening in unhealthy plants habitually prompt aggregation of sweet-smelling compounds particularly phenolic intensifies which are by and large more articulated in safe assortments [16, 6].

c. Plant protection from pathogenic organisms include various reaction: Pathways including the gathering of hydrolytic chemicals, for example, chitinases and ß-1, 3-glucanases [8, 42]. Phenols, peroxidase, and ß-1, 3-glucanases are fundamental segments of the reaction of a plant to different diseases and stress conditions, reacting working together with other safeguard-related proteins. These qualities could hence be utilized as markers for recognizing chickpea lines impervious to contagious microbes [56]. Because of the shifting nature of plants and microorganisms, biochemical changes happened at various phases of disease just as the development of the plant [51].

9. Primary Metabolism Effect in host plant

Essential Digestion Impact: Biotropic collaboration among host and microorganism initiates Receptive Oxygen Species which prompts customized cell death in have a tissue at the tainted site. Wound interceded Passage of the microorganism inside the host plant which was anticipated by the enlistment of guard qualities like arginase, cytochrome P450 monooxygenase, ATPases, Ser/Thr kinase, phospholipase C, and DNA methylation implies marginally early detecting of the microbe by having a plant. Enlistment of this load of qualities prompts adjusted essential digestion of the host, which includes changes in sugar as well as nitrogen digestion. This assertion was upheld over articulation of sugar and nitrogen digestion-related reproductions and carriers. These progressions in essential digestion may also control numerous primary and transcriptional controllers. All in all, it is anticipated that in viable communication of *Fusarium* sets up inside the host plant, triggers HR, focuses on the host's essential digestion and losses have obstruction. Then again, in safe plants the microorganism is detected early, its foundation inside the host is postponed, HR power is similarly lower than the vulnerable assortment, and host essential metabolic signs pay off for the microbe instigated harm[29].

10. **Utilization of safe cultivars:** The most extreme applied and cost-productive strategy for the executives of wilt of chickpea plant is the utilization of safe variety [28, 44, 45]. First recognized races 1, 2, 3, and 4 of *F. oxysporum f.* sp. *ciceris* in our country. Rearing practices help in protection from biotic anxieties and balance out chickpea creation. Reproducing rehearses have sponsored to fundamentally diminish the *Fusarium* wilt impact on the chickpea crop. There are fundamental three stages or parts are by and large engaged with any chickpea rearing system: i-hereditary variety, which is the foundation of the reproducing program; ii-choice inside that variety for attractive plant types with illness opposition and iii-assessment of the chose lines for business creation [52, 55]. Within the interim chickpea may be a self-pollinated plant, the progression of unadulterated line cultivars have to require settling qualities in replicating stream. Mass or unadulterated line choice from landraces was the least complex strategy at first utilized. A long way ahead, crossing programs and a few alterations of family and mass techniques were utilized in dealing with isolating ages [18]. Single crosses are embraced in most chickpea rearing projects, especially in various species hybridization among local and Kabuli-types having distinctive hereditary foundations [7]. Desi gatekeepers have been cast off move noteworthy qualities to shrink obstacles into Kabuli-type replicating programs, at that point once more, Kabuli gatekeepers have been utilized as a source to upgrade colossal seed measure as well as quality in neighborhood assortment raising ventures [19].

There is a need to improve the exactness and capability of determinations in the isolating ages for cutting edge and rapid hereditary additions [18]. Powerful wilt debilitated plots for the field and area of interest area screening, nursery, and lab methodology for opposition screening have been set up for fruitful reproducing programs [19].
Fusarium wilt is essentially overseen by obstruction rearing projects. Be that as it may, pathogenic changeability and impermanence promoting the breakdown of normally chose opposition are the fundamental obstacles for plant reproducers. Marker-helped quality planning contemplates have been finished by many exploration gatherings [22]. Numerous researchers have been investigated for post-pathogenic intrusion-related biochemical [16], which recommends that the opposition verses' *F. oxysporum* f. sp. *ciceri* in chickpea isn't represented by the old-style subordinate protection reactions operational in conventional plant-biotrophic experiences. These investigations underline the presence of some unusual protection component in this specific plant/microbe association [5].

Discussion
The researchers in the current investigation uncover that *Cicer arietinum* L. (Chickpea) is one of the significant yearly vegetable yields, developed all through India since old times. It is likewise filled in numerous nations worldwide. The yield has been confronting various biotic or abiotic imperatives. Among the biotic imperative harvest was influenced unfavorably by illnesses, brought about by numerous microorganisms. Since the time 1918 when interestingly wilt sickness of chickpea was accounted for and *F. oxysporum f.* sp. *ciceri* was the causal creature numerous methodologies have been received to control the wilt infection [10].
Dissimilar outcomes seen by the decision of planting time have been suggested for the board of *Fusarium* wilt of chickpea [28] yet those reports did not evaluate with regards to how these factors in pathogenesis would impact its productivity. The intuitive impacts of chickpea cultivar, planting date, or race of *F. oxysporum f.* sp. *ciceris* on wilt advancement and yield misfortune have not been resolved.
The comparative assessment was given by various researchers that, Chickpea filled in as a significant dietary protein for people at the least expensive expense contrast with different wellsprings of protein. Like different harvests, chickpea is exposed to numerous abiotic or biotic pressure, which causes restricted creation according to the hypothetical potential. The creation of chickpea in the subcontinent and Asian nations is seriously influenced by pathogenic growth [47, 49].
Biochemical changes in vulnerable and safe cultivars of chickpea were assessed based on significant biochemical mixtures like free amino acids, all-out phenol, ascorbic acids. Vulnerable and safe cultivars tainted with wilt infection were utilized for understanding biochemical instruments of sickness opposition [51]. Endeavors have been made to utilize interspecific crosses for improving hereditary fluctuation and introgressing valuable qualities from wild *Cicer* spp. into the developed species. Protection from Foc races has been distinguished essentially in Desi germplasm just as in wild *Cicer* spp.

Conclusion and Future Viewpoints
Fusarium wilt of chickpea certainly stays the indispensable danger in the dependable creation of chickpea around the world. This audit has been mirrored the reason for wilt infection and its impacts on chickpeas. *Fusarium* wilt is a major threat to chickpea creation misfortune. There is a need for a detailed investigation of the yield of misfortune due to *Fusarium* wilt in chickpea in the Indian area.
In the future, there is a need for investigation of all-out production loss of cultivar chickpea due to *Fusarium* wilt on chickpea in chickpea developing spaces of India. With the goal that legitimate work could be done in the future.No information accessible of yield misfortune and chickpea creation in an eastern locale of India. *Fusarium* illness becomes a challenge to the present-day horticultural economy since its impacts on chickpea are serious and it contaminates all pieces of the plants.
Moreover, there is a necessity of trademark on agro-climatic highlights influencing chickpea in all areas of India. Now, there is a need for sufficient examination to give agreeable clarifications to the in-plant pathogenic foundation and the comparing plant responses. Moreover, this specific pathogenic assault and its resultant host protection offer a chance for wide-going exploration.
Different hereditary and biochemical instruments are working in the safe cultivar for *Fusarium oxysporum* guard when contrasted with the weak plant. The guard-related

gene(s) ATPases, Ser/Thr kinase, phospholipase C, arginase, cytochrome P450 monooxygenase, and DNA methylation assumed a basic part in contributing regular protection from the safe host. Henceforth there is a need of developing a safe assortment of chickpea in various chickpea developing regions for more creation and yield.

Conflicts of interest

The authors declare no conflict of interest.

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