Evaluating the Dynamics of Mycorrhizal Populations and Wilt Severity in Chili Cultivation Regions

Abstract:

Chili peppers (*Capsicum annuum* L.) are a widely cultivated spice and vegetable globally, with their origins rooted in Mexico. The primary diseases impacting chili production encompass Anthracnose, Phytophthora, Leaf blight, Fusarium wilt, bacterial wilt, damping-off, and root rot, among others. In recent years, there has been a growing concern surrounding Fusarium wilt, caused by *Fusarium oxysporum*. This study aimed to investigate the fluctuations in mycorrhizal populations and the severity of wilt in chili farming regions within the state during the 2017-18 growing season. In each district, ten fields were examined, with two to three fields representing each village. The most substantial mycorrhizal colonization rate and the number of sporocarps in the soil were identified in Mahendragarh, with a mycorrhizal colonization rate of 17.3% and 260 sporocarps per 200 g of soil. Fatehabad district followed with a mycorrhizal colonization rate of 13.1% and 182 sporocarps per 200g of soil. The lowest values were recorded in Hisar district, with a mycorrhizal colonization rate of 11.5% and 138 sporocarps per 200g of soil. Wilt severity was most pronounced in Fatehabad district at 7.9%, followed by Mahendragarh at 7.3%, and was least severe in Hisar at 5.2%.

Keywords: Chili peppers, *Fusarium oxysporum*, Fusarium wilt, mycorrhizal colonization and mycorrhizal populations

Introduction:

In the realm of chili cultivation, a multitude of both living and environmental challenges pose significant constraints. Anthracnose, Phytopthora, Leaf Blight, Fusarium Wilt, Bacterial Wilt, Damping-Off, and Root Rot are notable diseases that negatively affect the production of chili. Among these, the appearance of Fusarium wilt, which is blamed on *Fusarium oxysporum*, has recently become a major issue. Chili plants face a multitude of pathogenic threats, with *Fusarium oxysporum*, responsible for vascular wilt, being the most predominant, leading to crop losses ranging from 10 to 50 percent globally and 10 to 80 percent in India (Bai et al., 2018).

India's primary chili-producing states include Karnataka, Madhya Pradesh, Andhra Pradesh, Bihar, and Maharashtra (Anonymous, 2017). In India, chili cultivation spans across 399 thousand hectares, yielding an annual production of 3737 million tonnes (Anonymous, 2019). In Haryana, chili occupies an area of 18.65 thousand hectares, yielding 130.96 million tonnes (Anonymous, 2017). Wilt, a highly destructive chili disease, substantially reduces yields by obstructing xylem vessels, preventing nutrient and mineral uptake by the plant, ultimately resulting in plant demise.

The Greek words "mycos," which means fungus, and "rhiza," which means roots, combine to form the term "mycorrhiza," which Frank first used in 1885. The term "mycorrhiza" denotes a cooperative relationship between fungus and vascular plant roots. These relationships increase the root surface area and increase the effectiveness of mineral uptake, which makes host plants more resilient to poor soil and drought conditions. Particularly well-known for its ability to promote plant growth and provide defense against soil-borne diseases such bacteria, fungus, and parasitic nematodes is arbuscular mycorrhiza (AM). It can be extremely difficult to eradicate these soil-borne plant diseases using standard fungicidal techniques.

Material and methods:

Study Area:

Comprehensive observations were made in both field and lab settings to look into the dynamics of mycorrhizal communities and the severity of wilt in chili farming sites within the state. A total of ten fields were chosen from each district, including Fatehabad, Hisar, and Mahindergarh, with two to three fields chosen from each hamlet. For laboratory studies, the CCS HAU, Hisar, Plant Pathology Laboratory was used.

Survey:

In each of the districts, namely Hisar, Fatehabad, and Mahendragarh, a total of ten fields were visited. At each field, ten chili plants were carefully uprooted, and their root systems were meticulously examined. The wilt intensity was assessed using a standardized scale, as outlined by Saha *et al.* in 2007. Approximately 250 grams of soil were collected from each site to estimate the sporocarp count within the soil, employing the method devised by Gerdemann and Nicolson in 1963. Root samples were also collected from each site and placed in polythene bags for the purpose of calculating mycorrhizal colonization in the roots, following the Phillips and Hayman method from 1970.

Mycorrhizal Colonization:

The calculation of mycorrhizal colonization was carried out by staining the roots according to the procedure outlined by Phillips and Hayman in 1970.

Staining of Roots:

The roots were initially cut into 1 cm segments and subjected to a series of treatments. These included heating the roots in a 10 percent KOH solution at 90°C for one hour, rinsing them with fresh 10 percent KOH solution, immersing the roots in alkaline hydrogen peroxide (H2O2) for 30 minutes, and then rinsing them with distilled water to eliminate excess H2O2. Subsequently, the roots were acidified with 5 N HCL for 30 minutes. The roots were then soaked in trypan blue in lactophenol (0.05 percent) for five minutes. Finally, any excess dye was removed by immersing the roots in lactophenol, and the stained roots were examined under a microscope.

$$\textbf{Mycorrhizal colonization (\%) in roots} = \frac{\text{Sum of all numerical ratings} \times 100}{\text{Total number of sample assessed} \times \text{Maximum scale}}$$

Estimation of sporocarp in soil

Determination of Sporocarp Quantity in Soil Using Wet Sieving and Decantation Technique as Described by Gerdemann and Nicolson (1963):

After carefully mixing the soil sample, 100 grams of this soil were suspended in a "Pan A"-branded container, to which one liter of water was added to ensure perfect mixing. The suspension was allowed to sit for 30 seconds before being run through a 20-mesh sieve, with the filtrate being collected in a different container known as "Pan B." At this time, the contents of "Pan A" were thrown away.

The suspension in "Pan B" was manually stirred and allowed to settle for a brief period. Subsequently, it was passed through a 60-mesh sieve, with the filtrate collected in a container labeled as "Pan C." The suspension within "Pan C" was then subjected to the next step, passing it through a 100-mesh sieve. The majority of mature sporocarps were retained on the 100-mesh sieve. The residue remaining on the 100-mesh sieve was collected in a beaker after thorough washing to remove any excess soil and other particles.

One milliliter of this solution was taken out and put in a counting dish. The sporocarp population in the soil was carefully inspected and counted under a stereomicroscope.

Wilt intensity:

$$\textbf{Disease intensity} = \frac{\text{Sum of all numerical ratings} \times 100}{\text{Total number of plant assessed} \times \text{Maximum scale}}$$

Saha *et al.* (2007) provided a scale for grading the Fusarium wilt disease.
0–3 scale for rating diseases
Resistant (R) = 0 = Infected not present, healthy
1 indicates moderate resistance (MR) and leaf yellowing
Plant wilting plus leaf yellowing equals moderate susceptibility (MS).
Susceptible (S) = 3 = Leaf yellowing plus plant wilting plus plant death

Results

Mycorrhizal Population Dynamics

The findings of the study reveal a range of values for mycorrhizal colonization, sporocarp numbers in the soil, and wilt intensity. Mycorrhizal colonization varied between 1% and 17.3%, sporocarp numbers in the soil ranged from 18 to 260, and wilt intensity ranged from 0.5 to 7.9. When we specifically look at mycorrhizal colonization and sporocarp numbers, Mahendragarh exhibited the highest values with 17.3% mycorrhizal colonization and 260 sporocarps per 200g of soil. Fatehabad district followed closely with 13.1% mycorrhizal colonization and 182 sporocarps per 200g of soil. Conversely, the minimum mycorrhizal colonization and sporocarp numbers were observed in Hisar district, registering at 11.5% mycorrhizal colonization and 138 sporocarps per 200g of soil. Within Hisar district, a notable disparity was observed between samples collected from different locations. In Hansi, mycorrhizal colonization was as low as 1%, with just 18 sporocarps per 200 g of soil. In contrast, the village of Kharar-Alipur reported the highest mycorrhizal colonization and sporocarp numbers, standing at 11.5% mycorrhizal colonization and 138 sporocarps per 200g of soil. A similar pattern of variation was observed in Fatehabad district, with the village of Dhani Bikaneri having the lowest mycorrhizal colonization (1.5%) and sporocarp numbers (20 per 200 g of soil). Meanwhile, Dani BinjaLamba exhibited the highest mycorrhizal colonization (13.1%) and sporocarp numbers (182 per 200g of soil) in the district. Lastly, in Mahendragarh district, Dongra Ahir recorded the lowest mycorrhizal colonization (7.4%) and sporocarp numbers (58 per 200g of soil), while Ateli reported the highest mycorrhizal colonization (17.3%) and sporocarp numbers (260 per 200g of soil) in the entire study.

Wilt intensity in the chilli field

During the agricultural season of 2017-18 in Haryana, a comprehensive examination of wilt intensity in chili crops was conducted. The findings revealed significant variation in wilt intensity across different districts. Fatehabad district emerged as the district with the highest wilt intensity, where it reached a substantial 7.9%. Following closely behind was Mahendragarh district, which displayed a wilt intensity of 7.3%. In contrast, Hisar district exhibited the lowest wilt intensity among the districts, recording a still notable 5.2%. A closer look within Fatehabad district revealed further variation in wilt intensity among different villages. Village Bhuna was identified as having the highest wilt intensity within the district, with a significant 7.9%. In stark contrast, Diwana village displayed the lowest wilt intensity in Fatehabad district, registering at a mere 1.0%. In Mahendragarh district, a similar pattern of variation was observed. Silarpur village recorded the highest wilt intensity within the district at 7.3%, while Ateli village reported the lowest wilt intensity, which was notably lower at 0.8%. Within Hisar district, yet another distinctive pattern emerged. Hansi, a locality within the district, exhibited the highest wilt intensity at 5.2%. In sharp contrast, Kharar-Alipur displayed the lowest wilt intensity within the district, with an impressively low figure of 0.5%. These variations in wilt intensity across districts and villages during the specified crop season underscore the significance of local factors and environmental conditions in influencing the severity of chili wilt disease.

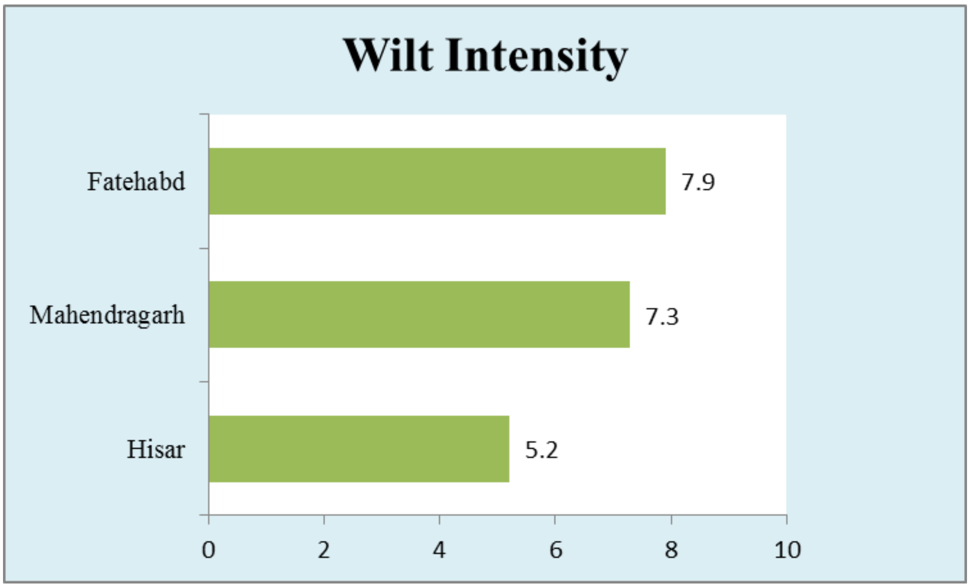

Plate 1: Investigation of chilli wilt severity across various haryana districts

Table 1: Analysis of the dynamics of the mycorrhizal population in the chilli fields (Haryana)

State	District	Locality	Mycorrhyzal colonizatio	Sporocarp number/ 200 g soil	Disease Intensity (%)	Myocrrhizal Species

			n (%)			
Haryana	Hisar	Hisar	5.3	100	2.5	*Glomus* sp.
		Hisar	4.0	82	2.0	-do-
		Hisar	2.0	56	1.8	-do-
		Hansi	1.0	18	5.2	*Gingaspora* sp
		Hansi	3.0	48	4.6	*Aculospora* sp.
		Balsamad	5.0	60	5.1	*Glomus* sp.
		Balsamad	3.0	84	1.6	-do-
		Kharar-Alipur	10.0	104	0.5	*Aculospora* sp.
		Kharar-Alipur	11.5	138	4.8	*Glomus* sp.
		Kharar-Alipur	10.9	98	3.2	*Glomus* sp.
	Fatehab ad	Dani Binja Lamba	12.2	102	6.1	*Gingaspora* sp.
		Dani BinjaLamba	13.1	182	2.8	-do-
		Bhuna	5.2	130	7.4	*Glomus* sp.
		Bhuna	4.3	84	7.9	-do-
		Saniana	10.1	140	4.1	*Gingaspora* sp.
		Saniana	11.2	170	6.8	-do-
		Dani Bikaneri	1.5	20	1.5	*Aculospora* sp.
		Kharakheri	5.0	106	3.2	-do-
		Kharakheri	11.3	180	5.4	*Glomus* sp.
		Diwana	9.0	152	1.0	-do-
	Mahend ragarh	Dongra jat	11.5	92	1.7	*Glomus* sp.
		Dongra jat	12.3	86	4.3	*Gingaspora* sp.
		Dongra jat	10.9	60	2.9	-do-
		Ateli	17.3	260	0.8	*Glomus* sp.
		Ateli	16.5	244	2.1	-do-

		Dongra Ahir	7.6	182	4.9	-do-
		Dongra Ahir	7.4	58	4.6	-do-
		Narnaul	15.2	192	5.3	-do-
		Silarpur	15.6	204	6.5	*Aculospora* sp.
		Silarpur	16.1	256	7.3	*Glomus* sp.

Discussion:

Arbuscular mycorrhizal fungi (VAM) play a crucial and versatile role in enhancing the health and nutritional status of plants. Their impact extends beyond the realm of nutrient uptake, encompassing multiple facets of plant resilience and protection against environmental stressors. One of the fundamental benefits of VAM is their ability to augment the absorption of essential elements by plants. Wang and Qiu's research in 2006 has documented how these fungi improve the uptake of phosphorus, a vital nutrient for plant growth. Moreover, VAM enhances the absorption of various other essential elements, including zinc, copper, sulfur, potassium, and calcium. This multifaceted nutrient acquisition contributes significantly to the overall health and vitality of plants. Additionally, VAM acts as a formidable defense mechanism against a range of environmental stressors. Giri *et al.* (2003) reported its effectiveness in shielding plants from soil salinity, a prevalent agricultural challenge that can impede plant growth. Al-Karaki et al.'s study in 2004 highlighted VAM's ability to mitigate the adverse effects of drought, a critical concern in regions with water scarcity. Furthermore, VAM has demonstrated its prowess in protecting plants from pathogens such as Fusarium wilt, as indicated by research conducted by Sawers *et al.* (2018) and Devi *et al.* (2023). This protective role extends to a fascinating concept known as mycorrhiza-induced resistance (MIR). Nguvo and Gao's work in 2019 uncovered that VAM-elicited MIR equips plants to defend against a broad spectrum of threats, including pathogenic fungi, generalist chewing insects, and necrotrophic pathogens. The correlation between the abundance of mycorrhizal fungi in soil and phosphorus content is a noteworthy finding reported by Dudeja *et al*. in 1997. This correlation underlines the intricate relationship between VAM and soil nutrient dynamics. Interestingly, the presence of mycorrhizal fungi is inversely related to the availability of phosphorus in the soil, illustrating the fungi's role in optimizing nutrient acquisition for plants. The specific study discussed in this context delves into mycorrhizal colonization, sporocarp numbers in soil, and wilt intensity in chili crops during the 2017-18 cropping season in Haryana. The results reveal a significant range in mycorrhizal colonization (from 1% to 17.3%), sporocarp numbers in the soil (ranging from 18 to 260), and wilt intensity in chili plants (varied from 0.5 to 7.9). Notably, Mahendragarh exhibited the highest mycorrhizal colonization and sporocarp numbers, while Fatehabad district closely followed. In contrast, Hisar district reported the lowest mycorrhizal colonization and sporocarp numbers. The broader context of similar studies underscores the variability in disease incidence in chili crops. For instance, Vani *et al.* (2014) found that Fusarium wilt initially affected chili nurseries and peaked during the flowering/fruiting stage, leading to reduced plant growth.

Umesha et al.'s survey in 2005 in Karnataka identified the presence of bacterial wilt disease, with disease incidence ranging from 26% to 32%. In Kadapa district, Andhra Pradesh, Bai *et al.* (2018) reported varying disease incidence rates from 6% to 24%. Meanwhile, Priya and Mesta (2018) conducted surveys in different districts, revealing a maximum wilt severity of 95% during the 2014-15 period. In conclusion, the role of VAM in plant health and protection is multifaceted, encompassing nutrient acquisition, stress resistance, and defense mechanisms. The study's findings on mycorrhizal colonization, sporocarp numbers, and wilt intensity in chili crops highlight the dynamic nature of these interactions and the complex interplay of factors influencing crop health. Understanding these intricate relationships is crucial for optimizing chili production and crop resilience in diverse agricultural contexts.

Conclusion:

Fusarium wilt poses a significant threat to chili plant health, resulting in substantial losses in chili productivity. This disease, primarily caused by *Fusarium oxysporum* f.sp. *Capsici*, is pervasive and affects pepper production across the country. The symbiotic relationship between mycorrhizal fungi and plants plays a pivotal role in determining the overall health of both the plant and the soil. This paper sheds light on the varying levels of wilt intensity and mycorrhizal presence across different districts of Haryana. Wilt intensity in chili crops exhibited a broad range, spanning from 0.5 to 7.9. The district of Mahendragarh, specifically Ateli, showcased the highest percentage of mycorrhizal colonization in plant roots and the greatest number of sporocarps in the soil. Fatehabad district, with Dani Binja Lamba as a notable location, followed closely behind. Conversely, Hisar district reported the lowest values for both mycorrhizal colonization and sporocarp numbers. Fatehabad district, specifically Bhuna, recorded the highest wilt intensity, with Mahendragarh's Silarpur district following suit. In contrast, Hisar district, particularly Kharar-Alipur, displayed the lowest wilt intensity. To effectively combat Fusarium wilt, it is imperative to develop integrated disease management strategies that incorporate compatible management options. Additionally, conducting epidemiological studies is crucial for gaining insights into the disease's dynamics and finding effective ways to mitigate wilt epidemics.

Disclaimer

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