Agric Res J **61** (3): 447-454, *June* 2024
DOI: 10.5958/2395-146X.2024.00057.4

EFFECT OF NUTRIENT SOURCES ON GROWTH OF *Fusarium* spp. CAUSING POD ROT OF MUNGBEAN

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ABSTRACT

Mungbean, a short-duration crop well-suited to dryland conditions, is cultivated in India during both the *kharif* and *rabi*/summer seasons. Recent years have witnessed a significant challenge in mungbean seed production due to pod rot caused by *Fusarium equiseti* and *Fusarium chlamydosporum*. This study investigates the growth characteristics of these pathogenic fungi under varying nutrient conditions. We evaluated eight different culture media to identify an optimal basal medium for the growth of these pathogens. Our findings indicate that both *F. equiseti* and *F. chlamydosporum* exhibited the highest colony growth rates on Potato Dextrose Agar, followed by Czapek's Dox Agar, Richard's Agar, and Corn Meal Agar. Furthermore, the fungi demonstrated varying abilities to utilize different carbon and nitrogen sources. Nutritional analysis revealed that sucrose, as a carbon source, and potassium nitrate, as a nitrogen source, were most effective in promoting the growth of both *F. equiseti* and *F. chlamydosporum*.

Keywords: Carbon sources, Culture media, Nitrogen sources, Plant pathogenic fungi

Mungbean [*Vigna radiata* (L.) Wilczek] is a crucial short-duration pulse crop extensively cultivated in India during both the *kharif* and *rabi*/summer seasons. In addition to its role as a food crop, mungbean serves as a valuable green manure due to its ability to fix atmospheric nitrogen through symbiotic nitrogen fixation, thereby mitigating soil nutrient depletion (Nadeem *et al.*, 2004; Pataczsék *et al.*, 2018). Despite these benefits, mungbean is highly susceptible to various abiotic and biotic stressors that can significantly reduce its productivity. Among these biotic stressors, fungal infections pose a major threat, contributing to yield reductions of up to 40–60% (Kaur *et al.*, 2011). Fungal pathogens can affect mungbean at different growth stages—including seedling, vegetative, and reproductive phases—leading to severe yield loss or even complete production failure.

Pod rot disease of mungbean, caused by *Fusarium equiseti* and *Fusarium chlamydosporum*, has recently emerged as a significant concern in India, particularly affecting crops grown during the *kharif* season (Buttar *et al.*, 2021). *Fusarium* species are ubiquitous, found in diverse environments including soils, plants, and the atmosphere. The presence and impact of *Fusarium* in soil and its subsequent infestation in plants are influenced by a range of factors. Geographical conditions, particularly climate and soil nutrition, play crucial roles in the occurrence and pattern of infestation by different *Fusarium* species. Additionally, the production of mycotoxins by *Fusarium* species is affected by both intrinsic and extrinsic factors (Shilpa *et al.*, 2011), and the mycotoxin profile of a species is influenced by the nutritional composition of its substrate (Koteswara Rao *et al.*, 2013). Crop nutrition can significantly impact disease resistance by enhancing mechanical barriers, such as strengthening cell walls, and by promoting the production of natural defense compounds. Keeping in view the variability observed in *Fusarium* species, this study investigates the cultural and nutritional aspects affecting these pathogens. Specifically, we explore the effects of different media, carbon sources, and nitrogen sources on the mycelial growth and sporulation of *Fusarium equiseti* and *Fusarium chlamydosporum*. The goal is to provide valuable insights for the effective management of pod rot disease.

MATERIALS AND METHODS

Isolation of pathogens from the symptomatic plants

Infected mungbean pods exhibiting symptoms such as discoloration, softness, distortion, and shrivelling, as well as white powdery mycelial growth, pod rot, white mouldy growth on seeds, and seed rotting, were collected from farmer fields, *Krishi Vigyan Kendras*, and Research Farms of Punjab Agricultural University, Ludhiana, between 2018 and 2021. These samples were transported to the laboratory in paper bags for further examination and isolation. Upon arrival, the pods were cleaned under running tap water, then chopped into small pieces. These pieces were placed

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Date of receipt: 01.11.2022, Date of acceptance: 04.05.2024

onto water agar medium after sterilization (Burgess *et al.*, 1994) and incubated under standard growth conditions (Salleh and Sulaiman, 1984). Subsequently, the cultures were transferred to Potato Dextrose Agar (PDA) and purified using the single spore isolation technique (Hansen, 1926). The purified cultures were incubated at 25 ± 1 °C. For further studies, all cultures were maintained on PDA and Spezieller Nährstoffarmer Agar (SNA) (Nirenberg, 1976) media.

Effect of culture media on growth of *F. equiseti* and *F. chlamydosporum*

Eight different media were tested for the growth of the pathogen, including Potato Dextrose Agar, Spezieller Nährstoffarmer Agar (SNA), Oatmeal Agar, Corn Meal Agar, Czapek's Dox Agar, Richard's Agar, Water Agar, and V8 Juice Agar. All media were prepared according to the manufacturer's instructions (HiMedia, India) and sterilized in an autoclave at 15 psi for 20 minutes before use. In a laminar flow hood, 20 ml aliquots of each medium were poured into sterilized Petri dishes under aseptic conditions. Each Petri dish was inoculated with 5 mm mycelial discs, extracted using a sterilized cork borer from 5-day-old cultures of the pathogen grown on Potato Dextrose Agar. The inoculated Petri dishes were seeded with actively growing 5 mm mycelial discs of the respective fungus using a sterilized inoculating needle, with four replicates for each medium. The inoculated Petri dishes were incubated in a BOD incubator at 25 ± 1 °C. Colony diameters were measured from four directions at 45° angles. The linear growth of the fungus was recorded in millimeters at 24-hour intervals over nine consecutive days. The radial growth rate (Kr) was calculated using the formula Kr = EW, where the radial growth rate is a function of the length (w) of the leading hyphae in the colony's peripheral growth zone and the specific growth rate (a) of these hyphae, as described by Trinci (1971). Additional colony characteristics, including colour, form, elevation, opacity, chromogenesis, and margin, were also documented.

Effect of carbon sources on growth of *F. equiseti* and *F. chlamydosporum*

The carbon requirements of the fungal pathogens *Fusarium equiseti* and *Fusarium chlamydosporum* were investigated by substituting sucrose in Richard's solution with various carbon compounds. The carbon sources examined included dextrose, glucose, mannitol, maltose, sucrose, lactose, citric acid, and galactose. The amount of each carbon compound was adjusted based on its molecular weight to provide an equivalent carbon content to that of sucrose in the basal medium. Each treatment was replicated thrice and sterilized at 1.1 kg/cm² pressure for 15 minutes. Separate sets of flasks were prepared for each pathogen. Cultures of *F. equiseti* and *F. chlamydosporum* were inoculated into the respective flasks and incubated at 27 ± 1 °C for seven and nine days, respectively. Dry mycelial weights for both fungi were recorded. Sporulation was assessed using a haemocytometer slide (0.01 cm²) under a compound microscope, following the methodology outlined by Tyagi and Paudel (2014).

Effect of nitrogen sources on growth of *F. equiseti* and *F. chlamydosporum*

The nitrogen requirements of the fungi were investigated by substituting potassium nitrate in Richard's medium with various nitrogen sources, including ammonium chloride, ammonium nitrate, potassium nitrate, sodium nitrate, peptone, and ammonium sulfate. The amount of each nitrogen compound used was calculated based on their molecular weights to ensure an equivalent nitrogen concentration to that provided by potassium nitrate in the basal medium. All nitrogen sources were sterilized at 1.1 kg/cm² pressure for 15 minutes. Following sterilization, the flasks were inoculated and incubated according to previously established protocols. The dry mycelial weight of both fungi was measured. Additionally, sporulation was assessed using a Haemocytometer slide (0.01 cm) under a compound microscope, as detailed by Tyagi and Paudel (2014).

Statistical analysis

The experimental design employed was a completely randomized factorial configuration with four replications. For statistical analysis, data were subjected to ANOVA, followed by Duncan's Multiple Range Test (DMRT) at a significance level of $p \leq 0.05$. All analyses were conducted using R Statistical Software version 4.1.2.

RESULTS AND DISCUSSION

Effect of different media on colony parameters of *Fusarium* species

Eight different test media were employed to evaluate their effects on the growth and colony characteristics of the fungus *F. equiseti*. The media used were Potato Dextrose Agar (PDA), V8 Juice Agar, Richard's Agar, Czapek's Dox Agar, Oat Agar, Corn Meal Agar, SNA, and Water Agar. The fungus displayed variable colony types across these media. Colony color and pigmentation were referenced using the RGB color code chart (https://www.rapidtables.com/web/color/RGB_Color.html). On most media, *F. equiseti* mycelium was typically white and aerial, except on SNA, Water Agar, and Corn Meal Agar, where it was sparsely distributed. The growth rate varied from moderate to good across different media,

with Water Agar and Corn Meal Agar exhibiting the slowest growth. Sporulation was induced by nearly all media, with the highest sporulation observed on Potato Dextrose Agar (1.65 x 10^6 conidia/ml) and the lowest on Corn Meal Agar (0.20 x 10^6 conidia/ml). Water Agar did not induce sporulation (Table 1). In terms of radial growth, *F. equiseti* demonstrated substantial growth on most media, with the mycelium reaching 90 mm in diameter within one week on Czapek's Dox Agar, Oat Agar, PDA, and Richard's Agar. In contrast, growth on SNA and V8 Juice Agar was somewhat less, at 63 mm in one week. The minimal radial growth was recorded on Corn Meal Agar. Overall, the radial growth rate across all media ranged from 0.29 mm/hr to 0.46 mm/hr. The highest growth rates were observed on Richard's Agar (0.46 mm/hr), PDA (0.45 mm/hr), Czapek's Dox Agar (0.42 mm/hr), and Oat Agar (0.42 mm/hr), while the lowest growth rates were noted on Water Agar (0.29 mm/hr) and Corn Meal Agar (0.32 mm/hr) (Table 2).

All tested media supported the production of conidia of *F. chlamydosporum* to varying degrees. The highest sporulation was observed on Potato Dextrose Agar (PDA), with a yield of 1.45 x 10^6 conidia/ml, followed by Czapek's Dox Agar (0.5 x 10^6 conidia/ml) and Richard's Agar (0.75 x 10^6 conidia/ml). The lowest sporulation occurred on Corn Meal Agar (0.20 x 10^6 conidia/ml), and no sporulation was detected on Water Agar (Table 3). The growth rate of *F. chlamydosporum* was evaluated across the eight test media, with the results summarized in Table 4. Czapek's Dox Agar exhibited the highest overall growth rate at 0.36 mm/hr, comparable to that on Potato Dextrose Agar, Richard's Agar, and Oat Meal Agar. In contrast, Water Agar showed the lowest growth rate at 0.20 mm/hr, which was slightly higher than Corn Meal Agar (0.21 mm/hr), SNA (0.23 mm/hr), and V8 Juice Agar (0.24 mm/hr).

Effect of carbon sources on growth and sporulation of *Fusarium* spp.

The carbon and nitrogen requirements of *F. equiseti* and *F. chlamydosporum* were investigated by substituting sucrose (the carbon source) and potassium nitrate (the nitrogen source) in Richard's medium with various alternative carbon and nitrogen compounds. The impact of these substitutions on fungal growth was assessed by measuring dry mycelial weight and sporulation. Data were collected to evaluate how different carbon and nitrogen sources influenced the growth and sporulation of both fungi.

The data revealed significant differences in the growth rates of *F. equiseti* and *F. chlamydosporum* when utilizing different carbon sources. For *F. equiseti*, the highest mean dry mycelial weight of 3.477 g and a sporulation rate of 1.52 x 10^6 conidia/ml were achieved with sucrose as the carbon source (Table 5). This was followed by dextrose, which resulted in a mean dry mycelial weight of 3.074 g and 1.55 x 10^6 conidia/ml. The lowest growth was observed with starch, yielding

Table 1. Effect of different media on the colony characteristics of *Fusarium equiseti* associated with pod rot of mungbean

Culture media	Colony characteristics of the fungus								
	Mycelium	Distribution	Growth rate	Form	Elevation	Margin	Opacity	Chromogenesis	Sporulation (conidia ml^{-1})
Corn meal	Without aerial	Sparse	Slow	Irregular	Flat	Undulate	Translucent	White	0.20 x 10^6
Czapek's dox agar	Aerial	Uniformly dense	Good	Irregular	Crateriform	Lobate	Iridescent	White and buff	1.5 x 10^6
Oat meal	Aerial	Uniformly dense	Good	Circular	Raised	Entire	Iridescent	White and buff	1.00 x 10^6
Potato dextrose agar	Aerial	Dense	Good	Irregular	Flat	Entire	Iridescent	White and buff	1.65 x 10^6
Richard's agar	Aerial	Uniformly dense	Good	Circular	Flat	Entire	Iridescent	White and buff	1.40 x 10^6
SNA	Without aerial	Sparse	Moderate	Irregular	Flat	Entire	Transparent	White	0.40 x 10^6
Water agar	Without aerial	Sparse	Slow	Irregular	Flat	Filiform	Transparent	White	-
V8 juice agar	Small Aerial	Dense	Moderate	Circular	Flat	Entire	Iridescent	White cottony	0.25 x 10^6

Table 2. Effect of different culture media on growth rate of *Fusarium equiseti* associated with pod rot of mungbean

Culture media	Colony diameter (mm) (Days after inoculation)							Growth rate (mm hr^{-1})*			
	1st	2nd	3rd	4th	5th	6th	7th	3-1 day	5-3 day	7-5 day	Overall growth rate
Corn meal	13.27	20.13	29.27	39.67	45.20	50.40	59.73	0.33	0.33	0.30	0.32^{a}
Czapek's dox agar	30.20	54.30	60.70	71.80	79.47	90.00	90.00	0.64	0.39	0.22	0.42^{b}
Oat meal	29.60	42.53	51.93	62.93	70.33	76.60	90.00	0.47	0.38	0.41	0.42^{b}
Potato dextrose agar	25.73	51.47	65.00	70.87	.80	80.93	90.00	0.82	0.20	0.32	0.45^{b}
Richard's agar	23.20	39.60	53.53	68.73	73.40	81.73	90.00	0.63	0.41	0.35	0.46^{b}
SNA	12.20	19.40	21.67	29.73	9.80	50.07	63.00	0.20	0.38	0.48	0.35^{a}
Water agar	11.00	19.67	24.60	30.70	0.80	49.13	52.33	0.28	0.34	0.24	0.29^{a}
V8 juice agar	12.60	19.67	21.67	29.67	9.80	50.07	63.00	0.19	0.38	0.48	0.35^{a}

*Radial growth rate of colony (Kr) = $(d_{i+1}-d_i) / (t_{i+1}-t_i)$
Within the last column, values followed by the same alphabets are not significantly different according to Duncan's Multiple Range Test (DMRT)

a mean dry mycelial weight of 1.087 g and 0.20 x 10^6 conidia/ml. No fungal growth was detected with citric acid as the carbon source. Similarly, for *F. chlamydosporum*, the maximum mean dry mycelial weight of 3.223 g and a sporulation rate of 1.30 x 10^6 conidia/ml were recorded with sucrose as the carbon source. This was followed by maltose, resulting in 3.125 g dry mycelial weight and 1.22 x 10^6 conidia/ml, and dextrose, which led to 2.857 g dry mycelial weight and 1.28 x 10^6 conidia/ml. Lactose and glucose provided mean dry mycelial weights of 2.445 g with 0.46 x 10^6 conidia/ml and 2.425 g with 0.60 x 10^6 conidia/ml, respectively. Starch was the least effective, supporting only 0.882 g dry mycelial weight and 0.10 x 10^6 conidia/ml. Like with *F. equiseti*, no growth was observed when citric acid was used as the carbon source.

Effect of nitrogen sources on growth and sporulation of *Fusarium* species

For *F. equiseti*, the highest dry mycelial weight of 4.562 g and a sporulation rate of 1.56 x 10^6 conidia/ml

Table 3. Effect of different culture media on the colony characteristics of *Fusarium chlamydosporum* associated with pod rot of mungbean

Culture media	Colony characteristics of the fungus								
	Mycelium	Distribution	Growth rate	Form	Elevation	Margin	Opacity	Chromogenesis	Sporulation (conidia ml^{-1})
Corn meal	Without aerial	Sparse	Slow	Irregular	Flat	Undulate	Iridescent	White	0.20 x 10^6
Czapek'sdox agar	Aerial	Sparse	Good	Circular	Flat	smooth	Iridescent	Ashy White to pink	0.95 x 10^6
Oat meal	Aerial	Uniformly dense	Good	Circular	Flat	Entire	Iridescent	White and pink	0.60 x 10^6
Potato dextrose agar	Aerial	Uniformly dense	Good	Irregular	Flat	Entire	Iridescent	White and pink	1.45 x 10^6
Richard's agar	Aerial	Uniformly dense	Good	Circular	Flat	Entire	Iridescent	White	0.75 x 10^6
SNA	Without aerial	Sparse	Moderate	Irregular	Flat	Entire	Transparent	White	0.30 x 10^6
Water agar	Without aerial	Sparse	Slow	Irregular	Flat	Filiform	Transparent	White	-
V8 juice agar	Small Aerial	Sparse	Moderate	Circular	Flat	Entire	Iridescent	White cottony	0.25 x 10^6

Table 4. Effect of different culture media on the mycelial growth of *Fusarium chlamydosporum* associated with pod rot of mungbean

Culture media	Colony diameter (mm) (Days after inoculation)									Growth rate (mm hr^{-1})*				
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	3-1 day	5-3 day	7-5 day	9-7 day	Overall growth rate
Czapek's dox agar	21.40	31.47	42.87	55.00	62.13	66.60	72.47	81.33	90.00	0.45	0.40	0.22	0.37	0.36^{b}
Potato dextrose agar	23.00	28.73	41.47	58.27	66.33	73.40	78.04	82.53	90.00	0.38	0.52	0.24	0.25	0.35^{b}
V8 juice agar	12.73	17.67	21.43	25.53	32.17	41.47	45.07	49.53	59.20	0.18	0.22	0.27	0.29	0.24^{a}
SNA	13.00	18.67	22.20	24.27	29.80	38.33	41.73	45.00	57.47	0.19	0.16	0.25	0.33	0.23^{a}
Richard's agar	24.07	29.73	41.00	55.13	65.13	75.07	78.53	83.73	90.00	0.35	0.50	0.28	0.24	0.34^{b}
Water agar	12.67	18.20	21.87	26.20	32.47	39.00	46.07	48.87	51.60	0.19	0.22	0.28	0.12	0.20^{a}
Corn meal	11.20	15.20	20.33	29.07	34.80	39.20	42.20	49.07	52.40	0.19	0.30	0.15	0.21	0.21^{a}
Oat meal	25.07	32.87	44.60	50.20	63.13	74.60	79.80	83.47	90.00	0.41	0.39	0.35	0.21	0.34^{b}

*Radial growth rate of colony (Kr) = $(d_{i+1}-d_i) / (t_{i+1}-t_i)$
Within the last column, values followed by the same alphabets are not significantly different according to Duncan's Multiple Range Test (DMRT)

were achieved using potassium nitrate as the nitrogen source, followed closely by peptone, which resulted in 4.330 g dry mycelial weight and 1.54 x 10^6 conidia/ml (Table 6). Sodium nitrate and ammonium sulfate yielded comparable results, with 3.650 g and 1.28 x 10^6 conidia/ml and 3.555 g and 1.32 x 10^6 conidia/ml, respectively. Ammonium nitrate (1.290 g and 0.12 x 10^6 conidia/ml) and ammonium chloride (1.179 g and 0.20 x 10^6 conidia/ml) also showed similar performance. For *F. chlamydosporum*, potassium nitrate was the most effective nitrogen source, supporting a dry mycelial weight of 4.197 g and a sporulation rate of 1.45 x 10^6 conidia/ml. There were no significant differences in growth when ammonium sulfate, peptone, and sodium nitrate were used as nitrogen sources. The lowest dry mycelial weight was observed with ammonium nitrate (1.062 g and 0.10 x 10^6 conidia/ml), followed by ammonium chloride (1.307 g and 0.12 x 10^6 conidia/ml).

The selection of an appropriate medium is crucial for maintaining fungal cultures and studying their various cultural characteristics. In the present investigation, among the eight solid media tested for the growth and sporulation of *F. equiseti* and *F. chlamydosporum*, optimal growth was observed on Potato Dextrose Agar (PDA), Czapek's Dox Agar, Richard's Synthetic Agar, and Oatmeal Agar. This can be attributed to the complex nature of these media, which effectively support fungal growth and sporulation. Similar observations were reported in other studies; for example, Thompson (2012) noted that *Fusarium* species exhibited maximum mycelial growth on PDA. Pardeep *et al.* (2013) investigated the growth of *F. moniliforme* on various media and found that PDA, Malt Extract Agar (MA), and Oatmeal Agar (OMA) were the most effective, with maximum mean growth of 74.96 ± 0.35 mm, 74.03 ± 0.25 mm, and 74.03 ± 0.15 mm, respectively. In another study, *F. chlamydosporum* showed abundant sporulation on Richard's Agar, Sabouraud's Agar, Malt

Table 5. Effect of carbon sources on mycelial growth and sporulation of *Fusarium equiseti* and *F. chlamydosporum*

Carbon source	*F. equiseti*		*F. chlamydosporum*	
	Mean dry mycelial weight (g)	Sporulation (conidia ml^{-1})	Mean dry mycelial weight (g)	Sporulation (conidia ml^{-1})
Glucose	2.857^{d}	0.90 x 10^6	2.425^{e}	0.60 x 10^6
Lactose	2.775^{e}	0.80 x 10^6	2.445^{d}	0.46x 10^6
Maltose	3.024^{c}	1.45 x 10^6	3.125^{b}	1.22x 10^6
Sucrose	3.477^{a}	1.52 x 10^6	3.223^{a}	1.30x 10^6
Mannitol	2.677^{f}	1.82 x 10^6	2.319^{f}	0.84x 10^6
Starch	1.087^{g}	0.20 x 10^6	0.882^{g}	0.10x 10^6
Dextrose	3.074^{b}	1.55 x 10^6	2.857^{c}	1.28x 10^6
Citric acid	0.000^{h}	-	0.000^{h}	-

Within a column values with the same alphabet are not significantly different according to LSD test

Table 6. Effect of nitrogen sources on mycelial growth and sporulation of *Fusarium equiseti* and *F. chlamydosporum*

Nitrogen source	*F. equiseti*		*F. chlamydosporum*	
	Mean dry mycelial weight (g)	Sporulation (conidia ml^{-1})	Mean dry mycelial weight (g)	Sporulation (conidia ml^{-1})
Potassium nitrate	4.562^{a}	1.56 x 10^{6}	4.197^{a}	1.45 x 10^{6}
Ammonium sulphate	3.555^{c}	1.32 x 10^{6}	3.786^{b}	1.42x 10^{6}
Peptone	4.330^{b}	1.54 x 10^{6}	3.837^{b}	1.22x 10^{6}
Ammonium nitrate	1.290^{d}	0.12 x 10^{6}	1.062^{d}	0.10x 10^{6}
Ammonium chloride	1.179^{d}	0.20 x 10^{6}	1.307^{c}	0.12x 10^{6}
Sodium nitrate	3.650^{c}	1.28 x 10^{6}	3.739^{b}	1.14x 10^{6}

Within a column values with the same alphabet are not significantly different according to LSD test

Extract Agar, and Potato Dextrose Agar (Sachidananda, 2005). Sharma and Pandey (2010) studied the colony characteristics of *F. oxysporum* on PDA, Czapek's Dox + Yeast Extract Agar (CYA), and Lignocellulose Agar (LCA), noting the development of a floccose, magenta-pink colony with concentric dark and light reddish zones. Additionally, Lazaratto *et al.* (2014) investigated the colony characteristics of *F. chlamydosporum* on Potato Sucrose Agar (PSA), Water Agar (WA), PDA, and Carnation Leaf Agar (CLA). They identified Potato Sucrose Agar and PDA as the best media for mycelial growth and sporulation under continuous light conditions, while CLA was also effective for sporulation. Water Agar was found to be less effective for the mass production of macroconidia.

Carbon is a fundamental structural component of fungal cells, essential for their growth and development. Fungi primarily fulfill their carbon requirements through various organic sources, with the range of usable substrates largely dependent on the organism's characteristics (Steinberg, 1950). Without an adequate carbon source, fungal growth ceases (Khilare and Ahmad, 2011). In the context of *F. oxysporum* f. sp. *cubense*, sucrose was identified as the most effective carbon source among seven tested options (Somu *et al.*, 2014). When evaluating the physiological effects of eight different carbon sources on soil fungi, including *F. oxysporum*, maltose, glucose, lactose, and sucrose were found to enhance fungal performance (Islam, 2015). Specifically, for *F. oxysporum* f. sp. *carthami*, maltose and starch yielded the highest growth, followed by glucose, fructose, sucrose, and mannitol (Shinde and Hallale, 2016). Patel (2020) investigated the impact of nine different carbon sources on *F. solani* grown on Czapek's Dox Agar and found that starch (7.96 ± 0.05 cm) and sucrose (7.93 ± 0.05 cm) were the most effective in promoting radial mycelial growth. This preference for sucrose and starch can be attributed to the fungi's ability to produce enzymes that hydrolyze these carbohydrates into usable sugars (Ravat and Basu, 2019). Regarding nitrogen, an essential element for protein synthesis, not all nitrogen sources support fungal growth equally. Patel (2020) tested ten different nitrogen sources on Czapek's Dox Agar and found that all supported good mycelial growth at a concentration of 1.5 g/L, except ammonium metavanadate and cobalt nitrate. Among the nitrogen sources, ammonium chloride (7.96 ± 0.11 cm) was the most effective for promoting growth, followed by ammonium nitrate (7.7 ± 0.1 cm) and ammonium sulfate (7.3 ± 0.1 cm).

The present study offers significant insights into the growth requirements and carbon and nitrogen preferences of *F. equiseti* and *F. chlamydosporum*, two prominent pathogens responsible for pod rot in mungbean. Our findings reveal critical information about how these fungi interact with various carbon and nitrogen sources, which is essential for understanding their growth dynamics and for developing effective disease management strategies. Our results indicate that *F. equiseti* and *F. chlamydosporum* exhibit a strong preference for sucrose as the primary carbon source, followed by maltose and dextrose. This is consistent with previous studies that highlight sucrose as a preferred carbon source for fungal growth due to its effective metabolism and utilization (Somu *et al.*, 2014; Islam, 2015). The observation that growth on other carbon sources was generally moderate aligns with the understanding that fungi have specific metabolic pathways optimized for certain sugars, which can influence their growth rates and sporulation capacities. The preference for sucrose, maltose, and dextrose reflects their ability to rapidly provide the necessary energy and structural components for fungal development. This insight is crucial for designing culture media that maximize fungal growth in both research and practical applications. The moderate growth on other carbon sources suggests that while these substrates can support fungal growth, they are less efficient compared to the preferred sugars. In terms of nitrogen sources, potassium nitrate emerged as the most effective, supporting the highest mycelial growth and sporulation for both fungi. This is in line with previous findings that

emphasize the role of potassium nitrate in enhancing fungal growth due to its high availability and suitability for protein synthesis (Patel, 2020). Peptone and sodium nitrate also supported significant growth, though to a lesser extent. This suggests that while various nitrogen sources can support fungal growth, potassium nitrate remains the most efficient for promoting optimal development. The lesser effectiveness of other nitrogen sources indicates that they may not provide the necessary nutrients or might require additional metabolic processing by the fungi, which can limit their overall growth and sporulation. Understanding these preferences helps in optimizing culture conditions for fungal research and offers potential strategies for controlling fungal pathogens by manipulating nitrogen availability.

The insights gained from this study have practical implications for managing pod rot in mungbean. By understanding the specific growth requirements of *F. equiseti* and *F. chlamydosporum*, researchers and breeders can better assess the risk of pod rot and develop targeted strategies to mitigate its impact. For instance, selecting or engineering mungbean cultivars with resistance to these pathogens, considering their nutritional preferences, could be a key approach in disease management. Additionally, the ability to modify growing conditions, including the optimization of carbon and nitrogen sources, could be utilized to suppress fungal growth and sporulation. This could involve adjusting agricultural practices to limit the availability of preferred nutrients to the pathogens or enhancing the nutritional profiles of mungbean cultivars to make them less susceptible to infection.

CONCLUSION

In conclusion, this study enhances our understanding of the nutritional requirements of *F. equiseti* and *F. chlamydosporum*, providing a foundation for improving disease management strategies for pod rot in mungbean. The preference for specific carbon and nitrogen sources by these fungi highlights the importance of tailoring growth conditions to both support beneficial research and to develop practical control measures. By integrating knowledge of fungal nutrition with cultivar development and management practices, it is possible to create more effective strategies for controlling pod rot and reducing its impact on mungbean crops.

Authors' contribution

Conceptualization and designing of the research work (HSB, A Singh, A Sirari); Execution of field/lab experiments and data collection (HSB); Analysis of data and interpretation (HSB); Preparation of manuscript (HSB).

Conflicts of interest

The authors declare that they have no conflicts of interest.

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