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Seasonal Shifts and Edaphic Drivers of Culturable Mycoflora in the Paddy Ecosystems of North Bihar

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Abstract

Soil fungi play a vital role in agricultural environments. They break down crop residues and help maintain soil health. Paddy ecosystems go through frequent changes due to flooding and tillage. We need to understand how fungal communities react to these shifts. This study looks at the culturable soil mycoflora in the paddy fields of North Bihar. The goal was to map their seasonal changes and figure out how soil conditions affect their numbers.

We collected soil samples from different depths in the fields. We used the serial dilution method and grew the samples on Potato Dextrose Agar. This allowed us to isolate and identify the aerobic and fast growing fungi present in the soil. We then counted the fungal isolates across different seasons. We compared these counts with soil moisture, temperature, and pH levels using statistical correlation.

The results showed twelve distinct fungal genera in the soil. The most common types were *Aspergillus, Penicillium, Fusarium,* and *Trichoderma*. Fungal populations reached their highest point during the monsoon season. We recorded 312 isolates during this wet period. The numbers dropped to 210 isolates during the dry summer months. We found a very strong positive correlation between the number of fungal isolates and soil moisture. The r value for this relationship was 0.86. Temperature had a moderate effect. Soil pH had a weak effect. We noticed that fungal diversity was much higher in the surface soil layer. The numbers fell sharply in the deeper soil layers.

These findings highlight how environmental factors shape the fungal community. Moisture is the main driver of fungal growth in these paddy fields. The topsoil contains the most organic matter from leftover crop stubble. This creates a perfect environment for fast growing saprophytic fungi to thrive. Genera like *Aspergillus* and *Penicillium* are excellent at breaking down this organic material. The high presence of Trichoderma is very promising. This fungus is known to fight off plant diseases naturally.

Our methodology mainly captured fungi that grow quickly on standard agar plates. This means we might have missed slower growing or strictly anaerobic fungi that live in flooded soils. However, the data still gives us a clear picture of the primary decomposer community. The natural abundance of these specific fungi suggests that the soil has a strong capacity for nutrient recycling.

Keywords: Soil mycoflora, Paddy ecosystem, Seasonal variation, Edaphic factors, Fungal diversity, Culturable fungi, Trichoderma

1. Introduction

Soil is a complex and living system. Fungi make up a massive part of this hidden biological world. They act as the primary decomposers in most terrestrial environments across the globe. These microscopic organisms break down tough plant materials like cellulose and lignin. This decomposition process releases trapped nutrients back into the earth. Plants then use these free nutrients to grow and thrive. A healthy fungal community ensures a steady supply of food for crops. Fungi do much more than just recycle dead plants. Many fungal species form close beneficial relationships with plant roots. Other species actively protect plants from harmful soil diseases. The balance of these fungal populations dictates the overall health of the soil ecosystem. When this delicate balance shifts the crop yields can suffer greatly. Farmers rely on these invisible workers to maintain fertile land year after year. Understanding how these communities survive is crucial for the future of sustainable agriculture.

Fungi produce powerful natural enzymes to survive. They secrete these chemicals directly into the surrounding dirt. The enzymes digest the complex plant matter outside the fungal body. The fungus then absorbs the resulting simple sugars for energy. This specific process is the engine of the global carbon cycle. Dead plant material would simply pile up indefinitely without soil fungi. The entire agricultural food web depends entirely on this microscopic breakdown process. The speed of this decomposition changes based on the types of fungi present in the dirt.

Paddy fields are highly unusual and stressful agricultural environments. Rice cultivation requires intense human intervention throughout the year. Farmers flood the fields with water for long periods. They plow the wet soil to create a thick dense mud. They often leave crop stubble to rot directly in the standing water. These farming actions create drastic physical changes in the soil ecosystem. The soil environment goes from dry and oxygen rich to completely waterlogged. The standing water displaces the air hidden in the tiny soil pores. This creates a severe lack of oxygen for the microbes living below the surface.

Most common soil fungi need steady oxygen to survive and grow. Only specific resilient types of microbes can handle these sudden environmental shocks. The constant cycle of flooding and drying forces the fungal community to adapt constantly. Species that thrive in dry airy conditions might die off completely during the monsoon. Many fungal spores simply lay dormant in the deep mud until the water recedes. The physical structure of the soil changes with every single plowing season. This constant physical disturbance makes paddy soils a fascinating subject for ecological study. The fungi must rebuild their microscopic networks every time a tractor turns the earth.

Environmental conditions heavily control all microbial life. Moisture is the single most critical factor for fungal growth. Fungal spores need water to germinate properly. Fungal threads require steady moisture to spread out through the soil matrix. Temperature plays an equally important role in this biological equation. Cold weather slows down fungal metabolism and stops their growth. Warm and wet conditions trigger explosive microbial reproduction. Soil acidity or alkalinity dictates exactly which species can survive in a specific field. These environmental variables are known as edaphic factors.

The changing seasons dictate these major edaphic shifts. The harsh transition from a scorching summer to a heavy monsoon completely rewires the soil biology. Heavy rains wash away certain surface nutrients while bringing in new raw organic matter. The top layer of soil experiences the most extreme temperature swings during the day. Deeper soil layers remain much more stable but possess less oxygen and available food. Fungi must navigate this complex three dimensional puzzle to survive the year. We must measure these exact environmental variables to understand daily fungal behavior. A slight change in soil pH can wipe out an entire beneficial fungal population.

North Bihar presents a very specific and challenging agricultural landscape. The region experiences intense humid summer heat followed by severe monsoon flooding. Agriculture remains the undisputed backbone of the local economy. Rice is the dominant crop across the entire region. Local farmers have grown paddy here for many generations. The soil in this region consists mostly of fertile alluvial deposits. Rivers flowing down from the Himalayas bring fresh sediment almost every year. This annual flooding renewal constantly changes the chemical makeup of the land.

Local farming practices now rely heavily on synthetic fertilizers and pesticides. These applied chemicals slowly alter the natural soil acidity over time. We must understand how the native fungi survive in this chemically modified dirt. The survival of these beneficial microbes directly impacts long term crop health. The region currently faces increasing weather unpredictability. Studying the baseline fungal populations helps us prepare for future climate stress. Global studies on agricultural microbiomes are very common today. Researchers have mapped soil fungi in many different global climates. We lack detailed specific information about the fungal communities native to North Bihar. The unique climate here creates a specific stress environment for all microbes. We do not fully know how these local fungi react to the extreme seasonal weather shifts. Identifying the native fungi is the vital first step to understanding this regional ecosystem. We need local data to make informed decisions about future agricultural practices.

This study addresses the missing regional biological data. The primary objective is to isolate and identify the dominant culturable fungi in these local paddy fields. The research maps exactly how these fungal populations change across different specific soil depths. We want to see where the highest biological fungal activity happens underground. Another key goal is to quantify the exact mathematical impact of the changing seasons. We measure how soil moisture temperature and pH affect the total number of fungal isolates. The final aim is to build a clear accurate picture of the edaphic drivers controlling this specific microbial world. This data will help improve local farming strategies.

Materials and Methods

We conducted the fieldwork across active paddy fields in North Bihar. We selected specific sites to capture the typical subtropical agricultural environment of the region. We collected soil samples during different seasons to observe temporal changes. We used a sterile stainless steel soil auger for the collection. We sterilized the auger with 70 percent ethanol before every single use to prevent cross contamination. We took samples from three precise soil depths. The first layer was 0 to 5 centimeters. The second layer was 5 to 10 centimeters. The deepest layer was 10 to 15 centimeters. We placed approximately 500 grams of soil from each depth into sterile polyethylene zipper bags. We sealed the bags immediately and transported them to the laboratory in an insulated cooler. We stored the samples in a laboratory refrigerator at 4 degrees Celsius to halt microbial growth before processing.

We used the serial dilution technique to isolate the fungi from the soil matrix. We performed all microbiological work inside a Laminar Air Flow chamber to maintain a completely sterile environment. We weighed exactly 1 gram of the fresh soil sample using a high precision digital balance. We transferred this soil into a sterile glass test tube containing 9 milliliters of sterile distilled water. We shook the tube vigorously on a vortex mixer for two minutes to detach the fungal spores from the soil particles. This created our primary soil suspension. We then took 1 milliliter of this suspension using a sterile micropipette and transferred it to a new tube with 9 milliliters of sterile water. We repeated this

exact transfer step several times to create a dilution series. We primarily used the final dilutions of 10^{-3} and 10^{-4} for our agar plating.

We prepared Potato Dextrose Agar as our primary growth medium. We sterilized the agar in an autoclave at 121 degrees Celsius and 15 pounds per square inch of pressure for 20 minutes. We allowed the liquid agar to cool slightly. We then added a small amount of streptomycin sulfate to the flask. This antibiotic completely stops unwanted bacterial growth without harming the fungi. We poured about 20 milliliters of the warm agar into sterile glass Petri dishes and let it solidify. We transferred 1 milliliter of our diluted soil suspension onto the solid agar surface. We spread the liquid evenly using a sterilized glass L shaped spreader. We sealed the Petri dishes with paraffin film. We placed the dishes upside down inside a digital BOD incubator set to 28 degrees Celsius. We left them there for five to seven days to allow the fungal colonies to grow fully.

We counted the visible fungal colonies on each plate after the incubation period. We used a digital colony counter pen to ensure accurate manual counting. We calculated the fungal population size in terms of Colony Forming Units per gram of dry soil. We used a standard mathematical formula for this calculation.

$$CFU = \frac{NXD}{W}$$

N = average number of colonies on the plate
D = dilution factor used
W = dry weight of the initial soil sample in grams

We examined every distinct fungal colony for identification. We observed the macroscopic cultural characteristics first. We noted the surface color, texture, shape, and the reverse side pigmentation of the colonies directly on the agar plates. We then performed microscopic examinations for accurate genus and species identification. We took a small portion of the fungal mycelium using a sterile inoculation needle. We placed the mycelium on a clean glass slide and stained it with Lactophenol Cotton Blue. We placed a cover slip over the sample and examined it under a compound light microscope at 400x magnification. We observed the structural details of the hyphae, conidiophores, and spores. We compared these observed microscopic features with standard taxonomic identification manuals written by Gilman and Barnett.

We measured three crucial edaphic factors for every collected soil sample. We measured the soil temperature directly in the field using a standard laboratory soil thermometer inserted into the ground. We brought a portion of the soil to the lab to determine its moisture content. We weighed exactly 10 grams of fresh soil on the digital balance to get the initial weight. We placed this soil in a hot air oven set to 105 degrees Celsius for 24 hours. We then weighed the completely dried soil. We calculated the moisture percentage using a specific equation.

$$\text{Moisture\%} = \frac{W1 - W2}{W1} \times 100$$

W1 = initial weight of the fresh soil
W2 = final weight of the oven dried soil

We determined the soil pH using a digital pH meter. We mixed 20 grams of dry soil with 40 milliliters of distilled water in a glass beaker. We stirred the mixture with a glass rod and allowed it to settle for 30 minutes. We calibrated the pH meter using standard buffer solutions before dipping the glass electrode into the soil suspension to get the final reading.

We finally analyzed how these environmental factors affected the total fungal counts across different seasons. We used the Pearson correlation coefficient formula to determine the statistical relationship between our variables.

$$r = \Sigma(X - \bar{X})(Y - \bar{Y}) / \sqrt{[\ \Sigma(X - \bar{X})^2 * \Sigma(Y - \bar{Y})^2\ ]}$$

X = specific edaphic factor like moisture or temperature
Y = corresponding total number of fungal isolates
$\bar{X}$ = mean value of X
$\bar{Y}$ = mean value of Y

This calculation gave us a precise number indicating how strongly the physical environment controlled the fungal population.

Results

The laboratory analysis yielded a vast amount of data regarding the soil fungal communities. We successfully isolated culturable fungi from all the soil samples collected across the different paddy fields. The serial dilution technique proved highly effective for bringing these microscopic organisms out of the dirt and onto our agar plates. We spent several weeks counting colonies and examining cell structures under the microscope. The final numbers reveal exactly how these communities are structured. The data shows how the fungi react to the changing physical environment of North Bihar.

We identified a total of twelve distinct fungal genera during the entire study period. A few specific groups completely dominated the soil environment. The genus *Aspergillus* emerged as the most abundant fungal group in the paddy fields. We found *Aspergillus* colonies on nearly every single Petri dish we processed. This genus accounted for 18.6 percent of the total fungal population isolated during the study. *Aspergillus* colonies grew very quickly on the artificial media. They started as white threads and rapidly turned into dark green or black powdery circles. Their ability to produce millions of tiny spores helps them dominate the topsoil.

Penicillium was the second most common genus we encountered. This group made up 16.3 percent of the total isolates. *Penicillium* colonies displayed a very distinct velvet texture. Their color was typically a vibrant blue green with a bright white outer edge. Under the microscope they looked like tiny delicate paintbrushes. *Penicillium* species are excellent at breaking down tough plant materials left behind after the rice harvest.

Fusarium ranked third in overall abundance. This genus represented 13.8 percent of the fungal community. *Fusarium* colonies looked like fluffy cotton candy on the agar plates. They often produced beautiful pink or purple pigments that stained the agar below them. Many *Fusarium* species are known plant pathogens. Their high presence in the soil indicates a constant disease pressure on the local rice crops.

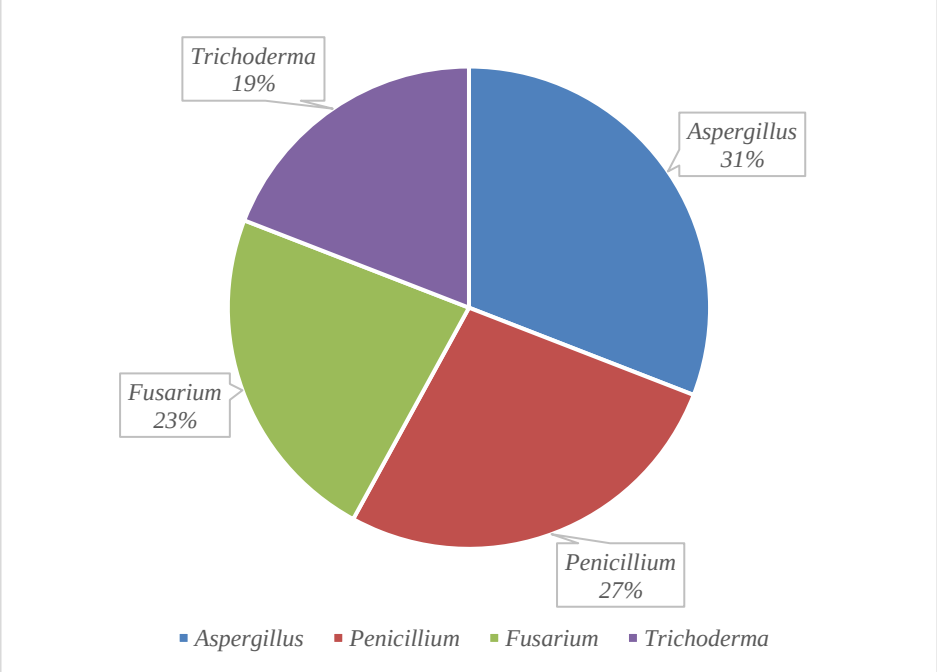
Trichoderma was the fourth major pillar of the fungal community. It comprised 11.5 percent of the total isolate count. *Trichoderma* grew faster than almost any other fungus in our laboratory. It formed dark green tufts that aggressively spread across the plates. *Trichoderma* is famous for its natural ability to attack and kill other harmful fungi. Finding such a large natural population of Trichoderma is very good news for the local farmers.

The remaining 39.8 percent of the fungal isolates belonged to eight other less frequent genera. These included groups like *Rhizopus* and *Mucor*. These specific fungi are known as sugar fungi. They grow incredibly fast and consume simple carbohydrates. We frequently spotted their tall fuzzy structures covering the plates within just two days of incubation. We found darker pigmented fungi like *Alternaria* and *Curvularia*. These fungi have thick dark cell walls. This dark pigmentation acts like a natural sunscreen. It helps them survive the intense summer heat when the soil dries out and bakes in the sun.

Table 1 Percentage Frequency of Dominant Fungal Genera Isolated from Paddy Soils

Genus	Percentage of Total Isolates
Aspergillus	18.6
Penicillium	16.3
Fusarium	13.8
Trichoderma	11.5
Other Genera	39.8

Chart 1 Visual Representation of Taxonomic Dominance



The physical depth of the soil dramatically changed the fungal population numbers. We divided our sampling into three separate horizontal layers to track this vertical distribution. The topmost layer was

from the surface down to 5 centimeters. The middle layer spanned from 5 to 10 centimeters. The deepest layer went from 10 to 15 centimeters deep.

We found the absolute highest concentration of fungal isolates in the surface layer. The samples from 0 to 5 centimeters contained 425 total fungal isolates. This top zone is where all the biological action happens. When farmers harvest the rice they leave behind roots and chopped stalks. All of this dead plant material sits in the topsoil. This organic debris is the primary food source for saprophytic fungi. The surface dirt is loose and well aerated. Fungi need oxygen to breathe and grow their networks. The combination of abundant food and high oxygen makes the top 5 centimeters a paradise for microbes.

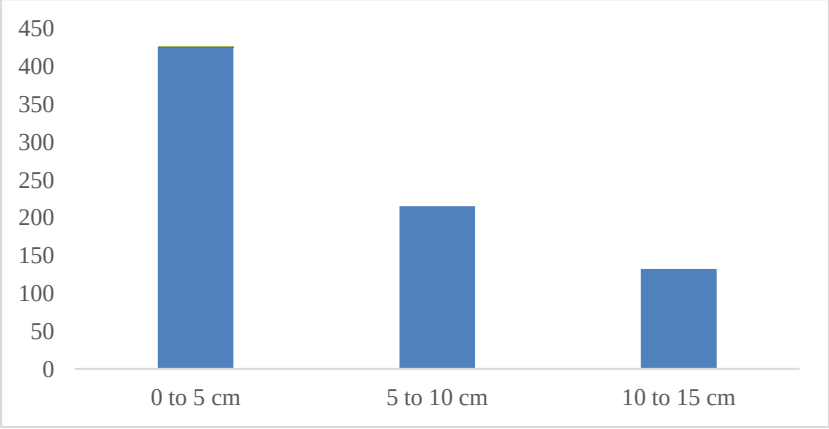
The middle soil layer showed a massive drop in fungal activity. We counted only 215 total isolates from the 5 to 10 centimeter depth. This is roughly half the number we found at the surface. The conditions become much tougher just a few inches underground. The soil is more compacted. There is far less fresh organic matter available to eat. The oxygen levels drop significantly. Only fungi that can tolerate lower oxygen and survive on limited food can thrive here.

The deepest soil layer contained the fewest fungi by far. We recovered a mere 132 isolates from the 10 to 15 centimeter depth. Paddy soils are frequently flooded. The water pushes all the trapped air out of the deep soil pores. This creates a completely anaerobic environment for long stretches of the growing season. Most of our culturable fungi simply cannot survive without oxygen. They either die off or go into a deep dormant state. The physical weight of the water and topsoil crushes the deeper mud into a dense brick. Fungal threads struggle to push through this heavy compacted barrier.

Table 2 Total Fungal Isolates Recorded Across Different Soil Depths

Soil Depth	Total Fungal Isolates
0 to 5 centimeters	425
5 to 10 centimeters	215
10 to 15 centimeters	132

Chart 2 Vertical Decline of Fungal Populations



The first bar representing the surface soil towers high above the others at 425 units. The second bar for the middle depth drops steeply to less than half that height. The third bar for the deepest soil is a small

stump resting at just 132 units. The visual trend is an unmistakable staircase stepping sharply downward into the earth.

The changing weather patterns of North Bihar triggered massive shifts in the soil biology. We tracked the total fungal isolates across the three major seasons to understand these changes. The seasons dictate the water levels and the temperatures of the fields. The fungi have no choice but to respond to these massive environmental swings.

The monsoon season produced the highest explosion of fungal growth. We recorded a massive total of 312 fungal isolates during these wet and humid months. The heavy summer rains finally break the dry heat. The water softens the hard soil clods. The humidity in the air and the moisture in the dirt reach peak levels. Fungal spores have been waiting in the dust for months. The sudden arrival of water signals them to germinate immediately. The monsoon moisture allows their microscopic threads to travel easily through the wet soil pores. They rapidly colonize the dead plant matter left in the fields. Trichoderma populations specifically skyrocketed during the monsoon. This aggressive fungus loves warm wet conditions.

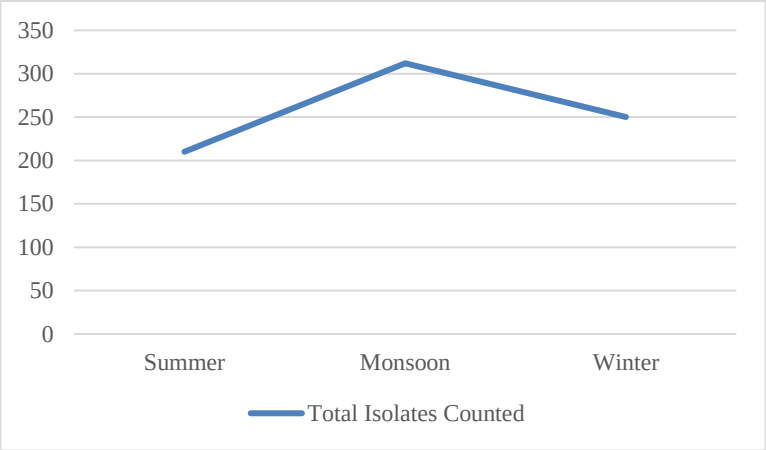
The summer months painted a grim picture for the soil microbes. The intense regional heat bakes the exposed paddy fields. The ground cracks open and the moisture evaporates completely. We recorded only 210 isolates during the summer season. This represents a severe drop in the living biological population. The dry heat destroys the fragile fungal threads. Most of the active fungi die. The surviving fungi rely on thick protective spores to wait out the drought. The dark pigmented fungi like *Alternaria* fared slightly better during this period. Their melanin packed cell walls protected them from the harsh solar radiation. *Aspergillus* also managed to maintain a decent presence due to its rugged spore structure.

The winter season offered a middle ground for the fungal communities. The temperatures drop significantly in North Bihar during the winter months. The soil retains some residual moisture from the previous monsoon. The morning dew provides a tiny daily dose of water to the surface. We counted an intermediate number of 250 isolates during this cool period. The extreme cold slows down fungal metabolism. They do not grow as aggressively as they do in the monsoon. They do not die off in massive numbers like they do in the summer. *Fusarium* species were very common during the winter. They prefer the cooler damp conditions to spread their fluffy white mycelium.

Table 3 Seasonal Variation of Total Fungal Isolates

Season	Total Isolates Counted
Monsoon	312
Winter	250
Summer	210

Chart 3 Seasonal Fluctuation Curve



Visualize a line graph tracking the fungal population over a full year. The line starts at a moderate height during the winter representing 250 isolates. As the timeline moves into the summer the line plunges downward into a deep valley at 210 isolates. This valley represents the harsh drought period. The line then shoots almost straight upward like a rocket as the timeline enters the monsoon season. It reaches a high peak at 312 isolates. This jagged mountain peak curve illustrates the extreme boom and bust cycle of life in a tropical paddy field.

We meticulously recorded the physical and chemical properties of the soil to match with our fungal counts. These environmental measurements are known as edaphic factors. We tracked soil moisture percentage along with soil temperature in Celsius and the soil pH. These three specific numbers tell the story of the underground habitat.

The soil moisture experienced wild swings throughout the calendar year. The moisture percentage hit a massive high of 65.4 percent during the monsoon season. The fields were practically mud soup. The winter soil held a moderate moisture level of 35.2 percent. The summer sun stripped the land dry leaving a miserable moisture content of just 15.6 percent. This dust like dirt is hostile to nearly all biological life.

The soil temperature readings followed the extreme climate above ground. The summer soil temperature peaked at a burning 38.2 degrees Celsius. This heat penetrates deep into the surface layer and cooks the delicate microbes. The monsoon rains brought a cooling relief that lowered the average soil temperature to 28.5 degrees Celsius. This specific temperature is the absolute perfect incubation warmth for most soil fungi. The winter dropped the dirt temperature down to a chilly 15.4 degrees Celsius.

The soil pH told a very different story. The acidity levels barely moved despite the changing seasons and heavy flooding. The soil remained constantly near neutral. The monsoon pH was 6.8. The winter pH was 6.7. The summer pH was 6.9. The heavy use of agricultural lime and specific synthetic fertilizers likely locks the soil chemistry into this stable narrow range.

Table 4 Average Edaphic Factors Recorded Across Three Seasons

Season	Moisture Percentage	Temperature Celsius	Soil pH
Monsoon	65.4	28.5	6.8
Winter	35.2	15.4	6.7
Summer	15.6	38.2	6.9

We used mathematical tools to prove exactly which of these environmental factors controlled the fungi. We calculated the Pearson correlation coefficient for each variable. This statistical test gives us a single letter r value. The closer the r value is to the number 1 the stronger the connection between the environment and the fungi.

The math proved that water is the absolute master of the paddy soil. The relationship between soil moisture and the total fungal isolate counts produced a massive r value of 0.86. This incredibly high number signifies a strong positive correlation. When the moisture goes up the fungal numbers immediately go up. When the dirt dries out the fungi disappear. The fungal biology in North Bihar is entirely dependent on the seasonal rain cycle. No other factor matters if the soil is bone dry.

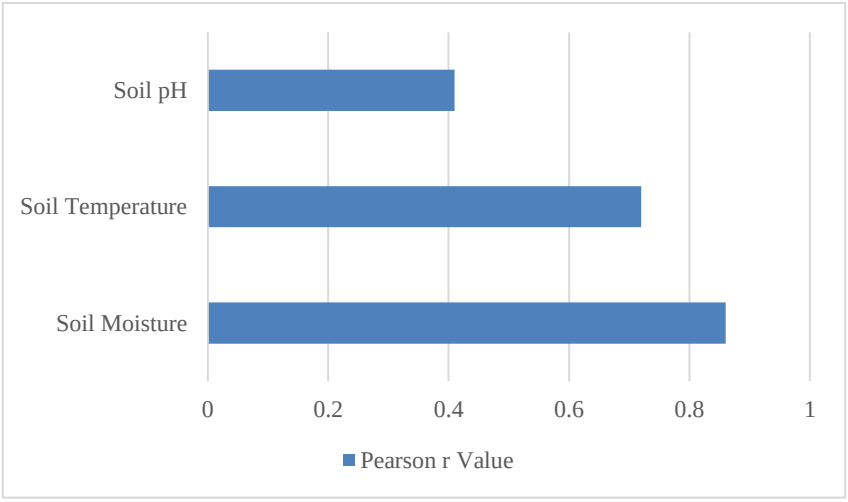
Table 5 Pearson Correlation Coefficients for Fungal Isolates and Edaphic Factors

Edaphic Variable	Pearson r Value	Correlation Strength
Soil Moisture	0.86	Strong Positive
Soil Temperature	0.72	Moderate Positive
Soil pH	0.41	Weak Positive

Soil temperature proved to be the second most important driver. We calculated an r value of 0.72 for temperature. This indicates a moderate positive correlation. Warmer temperatures generally push the fungi to grow faster and reproduce more often. A specific problem occurs during the extreme summer. The highest temperatures happen at the exact same time as the lowest moisture. The extreme heat alone would normally encourage growth but the lack of water cancels it out. The fungi only experience the benefits of warm temperature when the monsoon finally delivers the necessary water.

Soil pH had very little influence on the changing fungal numbers over the year. We calculated a low r value of just 0.41 for soil pH. This indicates a weak positive correlation. The slight shifts from 6.7 to 6.9 are not severe enough to kill or encourage any specific fungal groups. Most of the dominant genera like Aspergillus and Penicillium can easily tolerate a much wider range of acidity. The stable pH of the North Bihar fields acts as a quiet background condition rather than a driving force of biological change.

Chart 4 Strength of Edaphic Drivers



Discussion

The results show a very specific group of fungi dominating the North Bihar paddy soils. *Aspergillus* and *Penicillium* lead the population by a wide margin. These two genera are fast growing saprophytes. They excel at breaking down the tough plant materials left behind after the rice harvest. The abundant crop stubble in the topsoil provides them with an endless food supply. We found a high presence of *Fusarium.* This indicates that local rice plants face constant pressure from natural soil pathogens. The soil contains a large population of *Trichoderma* as well. This is a highly beneficial finding. *Trichoderma* naturally attacks and controls harmful fungi like *Fusarium*. A strong natural population of *Trichoderma* helps suppress crop diseases without the need for extra chemical treatments.

The physical location of these fungi tells us about their survival needs. The top five centimeters of soil contain the vast majority of the fungal community. Fungi require oxygen to grow their expansive underground networks. The surface layer provides plenty of air mixed with fresh organic debris. The environment changes drastically just a few inches deeper. The deeper soil layers are dense and heavily compacted from years of tractor use and continuous waterlogging. Oxygen struggles to penetrate this dense mud. The sharp drop in fungal numbers in the middle and deep layers makes perfect biological sense. Most culturable aerobic fungi simply cannot breathe or find enough food below the surface zone.

The changing weather patterns drive the massive shifts in fungal numbers throughout the year. The statistical data points to soil moisture as the absolute master variable. A correlation value of 0.86 proves that water dictates fungal survival in this ecosystem. The monsoon season provides the perfect combination of high humidity and soaked soil. Fungal spores germinate rapidly and spread their threads through the wet dirt to consume available nutrients. The summer months bring extreme heat and severe drought. The lack of water kills off active fungal growth and forces the survivors into dormant spore states. Temperature plays a supporting role in this cycle. Warmth encourages fast growth but only if the soil contains enough water. The soil pH remained relatively flat across all seasons. The constant use of synthetic fertilizers keeps the soil chemistry locked in a tight neutral range. This stable pH does not cause the massive seasonal population swings we observed.

We must acknowledge the limitations of our specific laboratory methods. We relied entirely on standard agar plating and serial dilution. This traditional culturing method introduces a strong biological bias. Potato Dextrose Agar heavily favors fast growing aerobic fungi. Genera like Aspergillus will quickly cover a plate and hide slower growing species. Paddy fields spend weeks completely flooded and starved of oxygen. Our aerobic laboratory methods likely missed the strictly anaerobic fungi that thrive during those flooded periods. We missed unculturable symbiotic fungi that require living plant roots to survive. The twelve genera we identified represent only the active decomposer fraction of the total soil microbiome.

This culturable fraction still provides excellent insight into the health of the local agricultural ecosystem. The native fungal community is perfectly adapted to the harsh cycle of floods and droughts. The strong presence of natural decomposers and protective fungi like *Trichoderma* proves the soil retains a robust biological capacity. Future research in North Bihar should combine these traditional plating methods with modern DNA sequencing. Extracting DNA directly from the paddy mud would reveal the hidden anaerobic fungi we could not grow in the lab. This complete picture will help farmers make better decisions regarding soil management and crop rotation.

Conclusion

This study provides a detailed look at the microscopic life hidden within the paddy fields of North Bihar. We successfully identified the primary fungal groups that survive in this demanding agricultural environment. *Aspergillus* and *Penicillium* stand out as the most common fungi in these soils. Their abundance makes perfect sense given the large amounts of leftover rice stubble they use for food. We recorded a significant presence of *Fusarium*. This indicates a constant threat of plant disease in the region. The notable population of *Trichoderma* offers a natural defense mechanism against those exact pathogens. These four groups form the biological foundation of the local soil ecosystem.

The physical location of these microbes follows a strict vertical pattern. The vast majority of the fungal community lives in the top five centimeters of the dirt. This surface zone provides the perfect mix of fresh organic material and breathable oxygen. The fungal numbers drop sharply as you dig deeper into the earth. The deeper mud is heavily compacted and lacks the air necessary for these specific aerobic fungi to breathe. This stark vertical decline proves that topsoil conservation is vital for maintaining a healthy microscopic workforce.

The changing weather dictates the overall rhythm of fungal life in this region. Our statistical analysis proves that soil moisture is the absolute most important factor controlling fungal growth. The heavy monsoon rains trigger a massive explosion in the microbial population. The fungi thrive in the warm and thoroughly soaked dirt. They use this wet period to expand their networks and reproduce rapidly. The brutal summer heat creates the exact opposite effect. The severe drought conditions force the population into a deep decline. Fungi must rely on thick spores to survive the harsh sun. Temperature changes influence how fast the fungi grow but only when adequate water is present. The hottest days of summer actually suppress growth because the soil is completely dry. Soil acidity remains mostly stable across the entire year. The continuous use of fertilizers likely prevents any major shifts in pH. This steady acidity plays a very minor role in the dramatic seasonal population swings we documented.

These findings carry real weight for local agricultural practices. The natural abundance of active decomposers means the soil can recycle its own nutrients efficiently. Farmers can rely on these microbes to break down harvest waste over the winter. The strong presence of *Trichoderma* is especially valuable. This fungus acts as a natural guardian for the rice plants. Encouraging the growth of these native beneficial fungi could reduce the strict dependence on expensive chemical treatments. A healthy soil microbiome acts as an invisible support system for the entire farm. Maintaining this biological health requires careful water and residue management. Leaving some crop waste on the surface ensures the fungi have enough food to survive the dry months.

We must remember the specific limits of our laboratory methods when interpreting these results. We used traditional agar plating techniques to grow these organisms. This approach heavily favors fast growing fungi that require oxygen to survive. Paddy fields spend a large portion of the year completely flooded. Our culturing methods completely missed the strictly anaerobic fungi that take over during those wet periods. We missed the slow growing species that cannot compete on a laboratory plate. The data represents the active aerobic decomposers rather than the entire biological picture.

Future research must build upon this foundational data using newer technology. Scientists should apply modern DNA sequencing directly to the paddy mud. This genetic approach will reveal all the hidden microbes that refuse to grow in a standard laboratory. Mapping the unculturable anaerobic fungi will complete our understanding of this unique flooded ecosystem. Long term monitoring over multiple years would help confirm these seasonal patterns. The paddy soils of North Bihar host a resilient and highly

adaptable biological community. Protecting this unseen ecosystem is essential for the future of local agriculture.

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