Claire Eveson
Saint Mary's School
Raleigh, NC USA
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India's Cereal Killer: Biodiversity's Effect On Crop Yield

According to the American Museum of Natural History, biodiversity is "the variety of life on earth at all levels" (American Museum of Natural History, 2025). This means biodiversity encompasses everything from the tiniest microbes in our soil to plants, fish, and even humans. Biodiversity also operates at three different levels: genetic diversity, the variability of genes within an organism or population; species diversity, the various types of organisms that make up the earth, fungi, animals, plants, and bacteria; and finally, Ecosystem diversity which is comprised of the abiotic factors such as water, and earth, and biotic factors, organisms, within an ecosystem (The Impacts of Conflict on Biodiversity in the Anthropocene). Additionally, when the biodiversity of a region is endangered, all organisms within that ecosystem are endangered due to disruptions in their way of life. For example, if one species of grass dies, then the animals that rely on that grass will starve, followed by the predators that eat the animals; this eventually will affect humans since, just like any other organism, we require food, water, and shelter, which is provided by the earth. Decreased biodiversity has already begun to affect human populations in India, where crop yields have been impacted by climate change and disrupted ecosystems. This poses the question of why decreased biodiversity affects crop yields in India and how to find a solution with sustainable agriculture.

India is located within the continent of Asia (Calkins and Allchin, 2018), and is the most populous country in the world, with a population of approximately 1.43 billion (The World Bank). India is a socialist democratic republic, which is federal in structure with unitary features. This means that India is a democracy that allows citizens to elect representatives and political officials. The Indian government is unique in structure as it adopts both unitary and federal government structures by dividing its region into states governed by local officials who are overseen by the federal government. It also places the national government in one state, New Delhi, which manages 28 Indian states. India's federal government is comprised of the Judiciary branch, which encompasses the Supreme Court, state courts, and district courts, the Legislative branch, which is a Bicameral Legislature with an upper house called Vidhan Parishad and a lower house named the State Legislative Assembly (Calkins and Allchin, 2018). The Executive branch includes the President, who serves as the head of state, and the Prime Minister, who serves as the head of government. The Prime Minister has the power to appoint the Union Council of Ministers, who essentially serve as a cabinet to both the Prime Minister and the President, while also overseeing their government ministries (Calkins and Allchin, 2018). The current president of India is Droupadi Murmu, and the Prime Minister is Narendra Modi (National Portal of India, 2023). That being said, the Indian President is more of a ceremonial position with the Prime Minister making most of the country's policies, enforcing them, and maintaining the plethora of public ministries implemented by the Union Council of Ministers. At the same time, the president mainly serves as the "face" for the Indian government (Raikar, 2024). Consequently, this means that the Union Council of Ministers is almost solely responsible for any progressive reform or practice changes within their designated category's jurisdiction. Some prominent positions include the Ministry of Defense, the Ministry of Development, and the Ministry of Education; however, there are also ministries whose sole responsibility is to create a federal policy for sustainable agriculture practice. The Ministry of Environment, Forest & Climate Change would oversee the national use and enforcement of sustainable agriculture practices, however, their influence on the state level is minimal, leaving it up to local governments to first create change on the state level ("The

Official Website of Ministry of Environment, Forest and Climate Change, Government of India").

The typical Indian family consists of approximately 5.2 people, about two times that of the average American family, which consists of 3.2 members (Haub and Sharma, 2008). India has a highly unequal distribution of wealth, contributing to largely separated upper and lower classes with little room in the middle classes. Those suffering from poverty are predominantly rural farmers. They commonly use mud roofs, floors, and other self-crafted homes. At the same time, wealthy upper-class families thrive in luxurious apartments within the city. Many Indian families do not rely on or have access to household amenities such as toilets, stoves, or air conditioners. In fact, in 2020, an estimated 57% of Indian households had a working toilet, contributing to poor sanitation and high rates of open defecation (Jain et al, 2023). Unfortunately, farmers in India tend to be poorer than the average Indian industrial or city worker, making it harder for them to invest in sustainable technology or strategies. Many farmers must choose between feeding their families and investing in expensive equipment like tractors, irrigation, or multiple crop seeds necessary for more sustainable agriculture. Additionally, land regulations are specifically made and regulated by the individual Indian states. Hence, the maximum land a farmer can own, who can buy land, and what they grow entirely depends on the state a farmer lives in, making it challenging to create reform on a national level. Farmland is almost always privately owned, with farmers purchasing the deeds; however, the local governments can set regulations on who can buy land (Trigunachadmin, 2024). Due to the high poverty rate in India, the typical Indian family's diet usually consists of cheap carbs, rice or flat breads, occasionally with a legume puree. Yogurt and exotic fruits are considered a luxury in India due to their higher cost, as they are more challenging to grow in the country's inconsistent climate and heavy rainfall, particularly during the monsoon season and summer. Therefore, non-native produce is less likely to survive and becomes more expensive (Climate of India - New World Encyclopedia, 2025). Native fruits more accustomed to India's diverse climate, such as bananas, jackfruit, grapes, and oranges, tend to be less expensive than imported varieties, such as tomatoes, apples, and blackberries, which are harder to acquire due to being costly to import and difficult to cultivate. (Kapoor et al., 2022) Unlike in the majority of Western countries, the cultivation of cattle is considerably rare as the vast majority of Indians are Hindus, who consider cows to be sacred. However, chicken is the most commonly consumed protein, usually in the form of kebabs often with rice; however, some Indians can afford goat and pig meat. (Devi et al.) This lack of agrodiversity in the Indian diet directly contributes to the high malnutrition rates in India's population. Approximately 14% of the total population of India is considered severely malnourished. In comparison, a staggering 36% of children's growth and development is stunted due to nutrient deficiencies, and 67% of children suffer from anemia caused by malnutrition (WFP 2025). This illustrates how a lack of agrodiversity can be directly linked to child malnutrition, as India's lack of food choices continues to decrease despite India being considered the eighth most biodiverse country in the world (Singleton, Sainsbury, 2006). This can largely be attributed to India's focus on the mass production of grains, as 59% of all farmland in India is used to cultivate grains, highlighting the country's focus on monoculture ("India - Global Yield Gap Atlas"). Finally, India's population continues to increase steadily and is expected to have a 0.89% increase in 2025 from the previous year, and is only expected to climb as healthcare becomes more available in rural areas, making it all the more urgent to find sustainable ways to feed the current Indian population (Macrotrends, Date).

This highlights the importance of agriculture and plant cultivation in sustaining India's population. However, many fail to recognize how protecting India's ecosystems and the organisms they contain is equally essential to crop production in Indian Agriculture. Perhaps the best example of biodiversity's importance within agriculture is demonstrated by agrobiodiversity. Agrobiodiversity is a type of genetic biodiversity that consists of humans selectively cross-breeding plants and livestock to create more genetic variation and, therefore, help build their tolerance to pests, climate, disease, etc. (The Impacts of Conflict on Biodiversity in the Anthropocene, rather than title, include author and year). However, as poverty and the Indian population continue to increase, agrobiodiversity and genetic biodiversity have declined. This is primarily due to a system of farming known as monocropping. Monocropping is the utilization of a single area of land over a long period to cultivate the exact crop and is commonly used for farming grains such as wheat. It was created to simplify farming and is an easy short-term solution for many impoverished farmers in rural areas, who may not be able to afford multiple fields or seeds; however, monocropping is not a sustainable method for farming. It creates long-term issues such as soil erosion, soil degradation, pest vulnerability, susceptibility to disease, and decreased biodiversity (Balogh, 2021).

Additionally, a study conducted in Rwanda found that increased usage of monoculture techniques in agriculture led to decreased vital soil elements such as carbon and zinc and increased susceptibility to diseases (Hashakimana Léonidas et al., 2023). Additionally, perhaps the biggest threat caused by decreased biodiversity is a fungus-born pathogen known as Blast Fungus or *Magnaporthe oryzae*. Blast Fungus forms from a fungal pathogen which damages every part of the rice crop and has evolved to infect other grains such as wheat, barley, millet and various other plants within the grain and grass families, forming an estimated total of 189 strains of blast fungus which evolved from the single original M. *oryzae* variant (Lan et al. 2020). Blast fungus can infect any part of the plant; however, it most commonly infects the leaves and the leaf nodes, which is how “Blast” enters the plant initially. The Blast Fungus spore is classified as a conidium, a spore composed of three cells. These spores can travel miles before landing on a host plant. The conidia are incredibly contagious and are most frequently spread by wind. They can travel in water or on other organisms, including people. The pathogen is a hemibiotrophic fungus, meaning that it goes through two phases of life when it starts the infection process. When the conidium is absorbed into a host plant, it attaches to the leaf cuticle, entering a biotrophic phase where it has not yet started feeding from the host plant. The Fungus can go dormant during the winter and wait between several seasons before favorable conditions are formed, generally when there is high humidity and heat. The Fungus will then form a dome-like structure on the leaf’s cuticle called an appressorium. The appressorium serves to form glycerol to force the plant to generate access melanin hence the brown color associated with the blast infection that will cause large amounts of water to exist the leaf cuticle to form turgor or water pressure to press down on a formation called a pressure peg that will be pressed down into the leaf cuticle by the accumulated water forcing the plant to allow the blast fungus to enter. The Blast fungus then releases biotrophic fungal cells known as hyphae that will multiply without triggering a response from the plant and wait a week before becoming lethal to the host plant. When the hyphae enter this necrotrophic phase, they steal nutrients from the plant directly and can spread through the shared root systems of neighboring plants, known as the plasmodesmata, killing an entire crop of wheat or grain in a little less than a week (Garcia et al.). Consequently, it is no surprise that “Blast Fungus” causes approximately 75% of yield losses yearly in India alone; however, it has also had devastating impacts on Japan, China, and Africa, which rely on wheat and rice as staple crops (“ICAR-NRCPB Scientists` Decoded Rice Blast Fungus (Magnaporthe Oryzae) Genome | ICAR”).

Although there is no known cure for crops afflicted with the “blast fungus” pathogen, steps can be taken to reduce the likelihood of infection and contain outbreaks to prevent the spread of the disease. One solution to prevent the spread of the Blast Fungus pathogens would be to consider the environmental factors that cause the spread and make rice particularly susceptible to the fungal pathogen, such as high humidity, heavy rain, and high winds, all of which are present during the monsoon season in India. Additionally, it would be necessary to address the external and internal factors that weaken or strengthen the rice, making it less or more susceptible to infection. Rice, just like any other organism, responds to external stimuli within its environment, which means that factors like flooding, overcrowding, and soil degradation caused by monocropping and the monsoon season weaken the plant while also providing the perfect conditions for the spread of Blast fungus. Therefore, by addressing the external factors that strengthen the blast fungus and weaken their crop, Indian farmers can protect their yields from the blast fungus by practicing crop rotation and planting their rice further from each other to reduce infection via the plasmodesmata. This helps reduce the likelihood of a farmer's entire yield being infected and can reduce the chances of one plant ruining the whole field (Chinnannan Karthik and Shu, 2023). Additionally research done in India has shown that by planting non host plants outside the grass and grain families in between the incubation seasons of the fungus the disease cycle of the pathogen can be purified, and therefore purge remaining pathogen from the soil, however this has yet to remove 100% of the pathogen from the soil (Kato, 2001).

Another pathogen known as Black Stem Rust is similar to Blast Fungus in the sense that both can be spread by wind and water over long distances, and remain in contaminated soil until they can successfully invade a host (Perumal Vidhyasekaran, 2004). Black Stem Rust is spread by the fungus Puccinia *graminis*, while Blast is spread by the fungus Magnaporthe *oryzae* (*Black Stem Rust and Barberry | Animal and Plant Health Inspection Service*, n.d.). Additionally, Blast is spread by a three-celled spore called a conidium, while Rust is only a two-celled spore called teliospores (Singleton & Sainsbury, 2007). Rust requires Barburry Bush to begin the lifecycle and to release Urediniospores, which can only infect wheat or other grain crops. Spores released into the air are known as aeciospores and are the most common cause of infection. Once a spore reaches a suitable host plant, it enters a dormant phase and becomes a teliospore until moist, warm conditions arise. Then it begins inserting hyphae, fungal appendages found in both Blast and Rust, to infiltrate the plant (Singleton & Sainsbury, 2007). The spore will then begin sexually reproducing by forming four basidiospores and then duplicates, leading to the eventual death of the host (Singleton & Sainsbury, 2007). While there is still no cure for afflicted crops, ways to prevent the spread of both the fungus and the Pathogen have been discovered and could provide possible solutions to India's Blast Fungus affliction. Seed treatments using Copper and sulfur-based fungicides have been seen to reduce the likelihood of infection. Still, due to the rapid lifecycle and reproduction of the fungus and the capacity to evolve, it is not a viable option for a long-term solution (U.S Department of Agriculture, 2024). Furthermore, with the resurgence of Rust in Africa through a new variety named Ug99, where 270 new resistant varieties have been and continue to be bred to combat the fungal pathogen, this possibly indicates the need for more focus on genetic biodiversity in India (Hayes, 2022).

Scientists have begun to identify genes in existing wild rice plants that are resistant to strains of the Blast Fungus pathogen responsible for the infection and have begun to breed more resistant varieties of wild rice with domesticated ones in hopes of creating a species that can survive the Blast Fungus. A recent study conducted in 2023 by a team of scientists in Wuhan, China, has begun using the DNA and gene-modifying software CRISPR-CAS9 to identify and replicate the blast-resistant genes found in wild rice to create new resistant strains. This highlights how new AI could help identify gene patterns within resistant rice species to find a solution to the Blast fungus (Dooley, 2023). Additionally, India has seen some success in discovering blast-resistant genes through Gene marking and tracking, and mapping the correlation between specific genes and susceptibility to blast fungus; however, they have yet to achieve significant results with generative or assistive technology, such as in China (Pote et al.). However, due to the rapidly evolving nature of the pathogen, gene programming and selective breeding are not reliable long-term solutions since the "ultimate" immunity gene has yet to be discovered, and with India's increasing population, an immediate solution must be found (Tanweer et al.).

Fungicides, specifically copper fungicides, have been used previously to eradicate Blast Fungus in Japan (Asibi et al.). However, copper fungicides are expensive and often damage the plant's leaves during heavy rainfall. Copper can also pollute the soil and, if misused, be absorbed into the plant, damaging and even killing it. Furthermore, copper fungicides cause heavy runoff, which leads to frequent pollution, especially in a humid country like India, which receives heavy rainfall annually (Gao et al.). One final possible solution for the Blast Fungus dilemma is to introduce *Streptomyces* bacteria into India's wheatfields as a protective barrier, as they have been discovered to show antifungal properties towards Blast Fungus and are aggressive in their eradication of the fungus with an 88.3% efficiency rate without harming local species, water sources or soil (Law et al.). It does this by producing antibiotic enzymes that not only weaken and kill the Blast Fungus but also strengthen the plant by producing volatile organic compounds and boosting the overall immune system of plants by releasing potassium and iron (Vurukonda et al.). Additionally, *Streptomyces* can eliminate lingering Blast fungus in soil between planting seasons as it is also resistant to cold temperatures and feeds from the soil (Law et al.).

Finally, based on this research, I recommend that Indian farmers implement three strategies to maximize their grain crop success and minimize damage caused by Blast Fungus. First, I would start by keeping a record of fields that have or had a history of being infected with Blast Fungus to avoid using fields in which the pathogen may be contaminated. Additionally, I recommend advancing the gene coding studies being conducted to breed resistant wheat and rice varieties to keep up with the rapidly evolving fungus. Finally, I would continue the research and utilization of Streptomyces bacteria since, unlike Copper fungicides, they can treat fields already contaminated with the fungus and prevent further outbreaks of Blast Fungus without contaminating the soil and water. With India's rapidly growing population, it is essential to consider how preserving its natural resources and increasing crop yield will benefit its growing population. As Blast Fungus can destroy up to 75% of Indian rice yield, India can deal with their population's food insecurity and feed future generations if it can be eradicated. Additionally, using sustainable agriculture methods, which secure biodiversity, India can protect their forests, animals, and people. By turning away from toxic copper fungicides, India will have greater access to clean water and fertile soil to continue farming its grain crops.

Works Cited

"Agriculture in India: Agricultural Exports & Food Industry in India | IBEF." *India Brand Equity Foundation*, www.ibef.org/exports/agriculture-and-food-industry-india.

American Museum of Natural History. "What Is Biodiversity? Why Is It Important?" *American Museum of Natural History*, American Museum of Natural History, 2019, www.amnh.org/research/center-for-biodiversity-conservation/what-is-biodiversity.

Asibi, Aziiba Emmanuel, et al. "Rice Blast: A Disease with Implications for Global Food Security." *Agronomy*, vol. 9, no. 8, Aug. 2019, p. 451, https://doi.org/10.3390/agronomy9080451.

Balogh, Allison. "The Rise and Fall of Monoculture Farming | Research and Innovation." *Projects.research-And-Innovation.ec.europa.eu*, 13 Dec. 2021, projects.research-and-innovation.ec.europa.eu/en/horizon-magazine/rise-and-fall-monoculture-farming.

Black Stem Rust and Barberry | Animal and Plant Health Inspection Service. (n.d.). Www.aphis.usda.gov. https://www.aphis.usda.gov/plant-pests-dieseases/black-stem-rust-barberry

Calkins, Philip B., and Frank Raymond Allchin. "India." *Encyclopædia Britannica*, 5 Dec. 2018, www.britannica.com/place/India.

Chinnannan Karthik, and Qingyao Shu. "水稻恶苗病及其防治策略之洞察." *Journal of Zhejiang University SCIENCE B*, vol. 24, no. 9, Springer Science+Business Media, Sept. 2023, pp. 755–78, https://doi.org/10.1631/jzus.b2300085. Accessed 12 Jan. 2025.

Climate of India - New World Encyclopedia. (2025). Newworldencyclopedia.org.

https://www.newworldencyclopedia.org/entry/Climate_of_India#google_vignette

"Decrease in Agricultural Holdings." *Pib.gov.in*, pib.gov.in/newsite/PrintRelease.aspx?relid=199780.

Devi, Subramaniam Mohana, et al. "An Outline of Meat Consumption in the Indian Population - a Pilot Review." *Korean Journal for Food Science of Animal Resources*, vol. 34, no. 4, Aug. 2014, pp. 507–15, https://doi.org/10.5851/kosfa.2014.34.4.507.

Dooley, Emily C. "Genome Editing Used to Create Disease Resistant Rice | College of Agricultural and Environmental Sciences." *Caes.ucdavis.edu*, 15 June 2023, caes.ucdavis.edu/news/genome-editing-used-create-disease-resistant-rice.

Fanzo, Jessica. "Biodiversity: An Essential Natural Resource for Improving Diets and Nutrition." *Agriculture for Improved Nutrition*, edited by Shenggen Fan et al., 1st ed., CABI, 2019. *Credo Reference*, https://credosource.infobase.com/articles/Qm9va0FydGljbGU6NDgyOTMxOA==?aid=17537.

Gao, Fei, et al. "Toxic Effects of Copper Fungicides on the Development and Behavior of Zebrafish in Early-Life Stages." *Nanomaterials*, vol. 13, no. 19, Multidisciplinary Digital Publishing Institute, Sept. 2023, pp. 2629–29, https://doi.org/10.3390/nano13192629. Accessed 4 Nov. 2023.

Garcia, Nalleli, et al. "Rice Blast Disease." *EDIS*, vol. 2024, no. 5, George A. Smathers Libraries, Oct. 2024, https://doi.org/10.32473/edis-mb009-2024.

globalreach.com, Global Reach Internet Productions, LLC-Ames, IA-. "The Importance of Biodiversity to Food and Agricultural Systems across the Globe."

Www.worldfoodprize.org, 16 Oct. 2017, www.worldfoodprize.org/index.cfm/88533/18098/the_importance_of_biodiversity_to_food_and_agricultural_systems_across_the_globe.

Green, R., Milner, J., Joy, E. J. M., Agrawal, S., & Dangour, A. D. (2016). Dietary patterns in India: a systematic review. British Journal of Nutrition, 116(1), 142–148. https://doi.org/10.1017/S0007114516001598

Hashakimana Léonidas, et al. "Comparative Analysis of Monocropping and Mixed Cropping Systems on Selected Soil Properties, Soil Organic Carbon Stocks, and Simulated Maize Yields in Drought-Hotspot Regions of Rwanda." *Heliyon*, vol. 9, no. 9, Elsevier BV, Sept. 2023, pp. e19041–41, https://doi.org/10.1016/j.heliyon.2023.e19041. Accessed 2 Feb. 2024.

Haub, Carl, and O. P. Sharma. "How People in India 'Really' Live." *PRB*, 18 Dec. 2008, www.prb.org/resources/how-people-in-india-really-live/.

Hayes, M. (2022, September 12). Saving the world's wheat - BGRI - Borlaug Global Rust Initiative. BGRI - Borlaug Global Rust Initiative. https://bgri.cornell.edu/saving-the-worlds-wheat/

"ICAR-NRCPB Scientists` Decoded Rice Blast Fungus (Magnaporthe Oryzae) Genome | ICAR." *Icar.org.in*, 2021, www.icar.org.in/node/5860. Accessed 12 Jan. 2025.

"India - Agricultural Land (% of Land Area) - 1961-2016 Data | 2020 Forecast." *Tradingeconomics.com*, tradingeconomics.com/india/agricultural-land-percent-of-land-area-wb-data.html.

"India - Global Yield Gap Atlas." *Www.yieldgap.org*, www.yieldgap.org/India.

Jain, Anoop, et al. “Prevalence of Zero-Sanitation in India: Patterns of Change across the States and Union Territories, 1993-2021.” *Journal of Global Health*, vol. 13, Edinburgh University Global Health Society, July 2023, https://doi.org/10.7189/jogh.13.04082.

Kapoor, R., Sabharwal, M., & Ghosh-Jerath, S. (2022). Indigenous Foods of India: A Comprehensive Narrative Review of Nutritive Values, Antinutrient Content and Mineral Bioavailability of Traditional Foods Consumed by Indigenous Communities of India. Frontiers in Sustainable Food Systems, 6. https://doi.org/10.3389/fsufs.2022.696228

Lan, Bo, et al. “Among-Population Genetic Diversity of Rice Blast Fungus Based on Fingerprinting of Virulence-Related Genes.” *Physiological and Molecular Plant Pathology*, vol. 112, Academic Press, Sept. 2020, p. 101554, https://doi.org/10.1016/j.pmpp.2020.101554.

Law, Jodi Woan-Fei, et al. “The Potential of Streptomyces as Biocontrol Agents against the Rice Blast Fungus, Magnaporthe Oryzae (Pyricularia Oryzae).” *Frontiers in Microbiology*, vol. 8, Jan. 2017, https://doi.org/10.3389/fmicb.2017.00003. Accessed 30 Sept. 2020.

Macrotrends. “India Population 1950-2024.” *Macrotrends.net*, 2024, www.macrotrends.net/global-metrics/countries/IND/india/population.

National Portal of India. “Governance & Administration | National Portal of India.” *Www.india.gov.in*, 2023, www.india.gov.in/topics/governance-administration.

Perumal Vidhyasekaran. (2004). Concise Encyclopedia of Plant Pathology. CRC Press.

Pote, Tushar Diliprao, et al. “Genetic Improvement of Traditional Basmati Rice Ranbir Basmati for Semi-Dwarfism and Blast Resistance through Molecular Breeding.” *Plant Gene*, vol. 32, Elsevier, Sept. 2022, p. 100386, https://doi.org/10.1016/j.plgene.2022.100386.

“Prime Minister of India | Description, Powers, Duties, Election, List, & Trivia | Britannica.” *Encyclopedia Britannica*, 2024, www.britannica.com/topic/Prime-Minister-of-India.

Rodriguez-Algaba, J., Boelt, B., Matzen, N., & Jørgensen, L. N. (2020). Fungicide application improves seed yield of perennial ryegrass upon infection with stem and crown rust fungi. Crop Protection, 134, 105178. https://doi.org/10.1016/j.cropro.2020.105178

Ruyle, L. E. “The Impacts of Conflict on Biodiversity in the Anthropocene.” *Encyclopedia of the Anthropocene*, by Michael Goldstein, 1st ed., Elsevier Science & Technology, 2017. *Credo Reference*, https://credosource.infobase.com/articles/Qm9va0FydGljbGU6NDgyNTc5NQ==?aid=17537.

Singleton, P., & Sainsbury, D. (2007). Dictionary of microbiology and molecular biology. Wiley.

Tanweer, Fatah A., et al. “Introgression of Blast Resistance Genes (Putative Pi-b and Pi-Kh) into Elite Rice Cultivar MR219 through Marker-Assisted Selection.” *Frontiers in Plant Science*, vol. 6, Dec. 2015, https://doi.org/10.3389/fpls.2015.01002. Accessed 5 Mar. 2020.

“The Official Website of Ministry of Environment, Forest and Climate Change, Government of India.” *Moef.gov.in*, 2020, moef.gov.in/.

The World Bank. “Data Development Hub.” *Datacatalog.worldbank.org*, 20 Dec. 2023, datacatalog.worldbank.org/search/dataset/0037712.

Thomas Felix, K., & Ramappa, K. B. (2024). Fruit Frenzy: Evolving Consumption and Demand Trends in South India. THE INDIAN JOURNAL of AGRICULTURAL ECONOMICS, 79(3), 349–369. https://doi.org/10.63040/25827510.2024.03.002

trigunachadmin. “World Class Farmlands near Bangalore.” *Triguna Country Homes*, 14 Dec. 2024, trigunacountryhomes.com/legal-aspects-of-farmland-ownership-in-india-what-you-need-to-know-before-making-a-purchase/. Accessed 10 Mar. 2025.

Unit, Biosafety. “Main Details.” *Www.cbd.int*, www.cbd.int/countries/profile?country=in.

urediniomycetes (rust fungi; rusts). (2006). In P. Singleton & D. Sainsbury, Dictionary of Microbiology & Molecular Biology (3rd ed.). Wiley. https://credosource.infobase.com/articles/Qm9va0FydGljbGU6OTU4NDE0?aid=17537

Vurukonda, Sai Shiva Krishna Prasad, et al. “Plant Growth Promoting and Biocontrol Activity of Streptomyces Spp. As Endophytes.” *International Journal of Molecular Sciences*, vol. 19, no. 4, Mar. 2018, p. 952, https://doi.org/10.3390/ijms19040952.

“WFP India Country Brief, January 2025 - India.” *ReliefWeb*, 11 Feb. 2025, reliefweb.int/report/india/wfp-india-country-brief-january-2025. Accessed 10 Mar. 2025.

Wheat Rust Diseases | Crop Science US. (2024, July 8). Www.cropscience.bayer.us. https://www.cropscience.bayer.us/articles/cp/wheat-rust-diseases

WorkingAbroad. “India Climate and Geography | WorkingAbroad.” *Working Abroad*, 24 Apr. 2019, www.workingabroad.com/travel/india-climate-and-geography/.

World Food Programme. “India | World Food Programme.” *Wfp.org*, World Food Programme, 19 Nov. 2019, www.wfp.org/countries/india.