SATSA Mukhapatra - Annual Technical Issue **28** : 2024 ISSN 0971-975X **Invited Paper**

Sustainable Management of Rice Diseases : A Model for Smart Farming and Sustainable Rice Production

Manas K. Bag[1], Prahlad Masurkar[2], Anuprita Ray[2], Partha S. Roy[3]*

(Received : January 08, 2024; Revised : January 14, 2024; Accepted : January 15, 2024)

ABSTRACT

To feed the burgeoning population intensive farming practices are the right option to growers. But intensive farming infuses heavy use of chemicals like fertilizers, pesticides, adaptations of monoculture of hybrids and high yielding varieties of crops. Intensive farming practices with drastic changes in climatic condition over the years has influenced the intensity of crop diseases and pest attack. Rice is not a exception and eventually this crop also affected by the same practices. Sustainable management balances all aspects starting from maintaining environment that includes soil, water conservation and microbial equilibria to plant and animal health vis-à-vis human health. Thus, in this article it is tried to narrate howrice diseases are managed sustainably.

Key words : Sustainable agriculture, Rice diseases, Precision agriculture, Nano-materials, Microbial consortia, Diversity.

Introduction

Sustainable developmentin agriculture has emerged as a crucial paradigm in front of global challenges such as climate change, resource depletion, and food security concerns (Sandhu, 2021). The traditional methods of farming, characterized by intensive chemical inputs and unsustainable practices, have often led to environmental degradation and long-term soil health issues. In this context, sustainable agriculture seeks to strike a balance between meeting the current agricultural needs and preserving the resources for future generations. In addition to addressing the current risks to crop health, sustainable rice disease management considers the long-term effects on biodiversity, the environment, and farmer livelihoods (Garibaldi *et al.*, 2017). We can create resilient agricultural systems that reduce our dependency on artificial inputs and enhance the overall sustainability of rice production by adopting creative and holistic approaches.

Since rice is a staple food for a large percentage of people worldwide, it is essential to global food security. Conventional rice farming methods, however, have been linked to several social and environmental issues. Not only does the application of sustainable agricultural

[1]Crop Protection Division, ICAR- National Rice Research Institute, Cuttack, Odisha-753006*Corresponding E-mail id: manas.bag@gmail.com; Manas.Bag@icar.gov.in; [2]Lovely Professional University, Phagwara, Punjab, 144001; [3]O/O The Assistant Director of Agriculture (Admn), Medinipur Sadar Subdivision, Abash, Paschim Medinipur, West Bengal.

concepts to rice cultivation solve these problems, but it also shows to be a workable way to lessen the difficulties caused by rice diseases. However, there are several obstacles to the sustainable cultivation of rice, and diseases are a major threat to both quality and productivity. It is more important than ever to employ economically and environmentally sound solutions to combat rice diseases as we traverse the intricacies of modern agriculture (Manoharachary and Kunwar, 2014). In the context of rice disease management, sustainable agriculture can be applied through the application of techniques that minimize environmental effects while fostering long-term soil health, biodiversity, and disease resistance. This strategy places a strong emphasis on the value of precision agriculture, organic farming, genetic diversity status, and agroecological techniques in the sustainable management of rice diseases. The main ideas of sustainable agriculture have been discussed in this review, with how they relate to rice disease management (Albahri *et al.*, 2023). Crop rotation, reverse cropping system, resistant varieties, water management, cover crops for organic farming practices, water management, crop residue management, biological control agents, crop green manure, precision agriculture, community participation, monitoring & early detection, and agroecological zoning are some strategies which help in the management of rice diseases (Liu *et al.*, 2023).Sustainable rice disease management is established, emphasizing the value of implementing strategies that support ecological balance, protect natural resources, and strengthen rice crops' resistance to changing disease threats (He *et al.*, 2021). In addition to increase the quantity and quality of their rice harvests, farmers can support the larger objectives of social welfare and environmental preservation by implementing sustainable farming practices.

Crop rotation

Crop rotation isan effective but relatively expensive means of managing disease. Successful utilization of crop rotation requires understandingof the life cycle of the pathogen (Francis and Clegg, 2020). In this method growing one season of non-host crop in the field, so the pathogen could not survive and die which couldlead to a break in the host-pathogen cycle. Crop rotation altersthe physical, and chemical properties of the soil, and stimulates beneficial microbial activity. 3-year rotation of rice, soybean,and corn, was found to be effective against the rice false smut diseases (Brooks, 2009). It was also found that furrow-irrigated rice cultivation systems recorded low disease severity compared to puddled rice fields. It is because of reduced survival period of chlamydospores in soil.

Kumar *et al.* (2020) found that the cropping intensification of rice - followedby the inclusion ofwinter crops like chickpeas, lentils& safflower also found to reduce the incidence of rice diseases. In addition to intensification conservation tillage practices like zero tillage in direct-seeded rice could be a strategic option for disease managementwith productivity, energy use efficiency, emission of greenhouse gases, crop rotation in the rice growing areas quite a potato also promotes the reduction of a blast disease of rice also seen (He *et al.*, 2021).

Organic farming

Pest and disease control based on the organic farming is usually maintenance of soil fertility by balanced crop rotations, including the use of nitrogen-fixing crops, winter crops, additional manure of compost,and reduction in soiltillage (Xu *et al.*, 2021). In the rice-crop ecosystem when organic farming was applied it was found that first two years the yield was reduced up to 10-20% in comparison to inorganic fertilizers, however during the later two years it has been improved (Vaglia *et al.*, 2022).

In the organic system, the disease incidence is also reduced because of competition for space and food between the microorganisms.In the use of chemical fertilizers, the sufficient N, -related nutrients cause the excessive accumulation of nutrients in the seedlings might have toxic effects and weaken their immune system, while rice plants treated with a suitable amount of organic manure showed a better capability of disease resistance of grew healthier (Panth et al., 2020). Nuryanto *et al.*, 2022 done the soil amendment with rice, shows compost & found a significantly reduction in sheath blight severity. In manure compost, *R. solani*prapagules in the form of sclerotia germination were suppressed by mycopasitismand the maturity level of compost also found to enhance the inhibition of sclerotica germination (Kumar *et al.*, 2023).

Precision agriculture

Precision agriculture can have a significant impact on reducing the dependency on plant protection products for crop protection (Anastasiou *et al.*, 2023). The scattered distribution of disease in fieldswas only can be mapped by the sensor system and can potentially decrease by applying pesticides only as needed in the field andthereby decrease environmental impact. Image processing techniques which help in accurate and timely detection of disease and overcome the limitations of human eye. Minimum distance Classifier & K-Nearest Neighbour Classifier has been used for the identification of rice blast, bacterial leaf blight, rice brown spot and sheath blight of rice. The accuracy achieved by using K-NN & MDC is 87.02% and 89.23% respectively (Joshi and Jadhav 2016).

One of the precision agriculture technology is hyperspectral imaging. The standard deviation (STD) of the spectral reflectance of whole rice leaves andconstructed support vector machine (SVM) andprobabilistic neural network (PNN) models has been used to classify the degree of rice leaf blast at different growth stages. STD based SVM Model were found most effective for identification do rice blast (Zhang *et al.*, 2022).

Remote sensing proves to be particularly effective for optimizing precision management strategies for soil-borne diseases and nematodes due to visible changes in foliage characteristics resulting from root damage, the tendency of infections to cluster in specific areas, slow pathogen mobility in soil impeding spatial disease spread, limited introduction of new disease foci, and the applicability of disease maps from one season to future cropping seasons (Oerke, 2020). Thus, precision agriculture techniques, such as remote sensing and geospatial technologies, offer effective tools for monitoring and managing soil-borne pathogens and optimizing disease management strategies.

For the prediction of the severity of rice blast disease a machine learning model i.e. SMOTE developed. Multispectral remote sensing technology has been applied for the detection of rice sheath blight disease (Bhatia *et al.*, 2021). In this multispectral remote sensing technology applicability of broadband high spatial-resolution ADAR (Airborne Data Acquisition and registration) remote sensing data hasbeen utilized. Based on field symptom measurement, a comprehensive field disease index (DI) was constructed to measure the infection severity of the disease andto relate to image-sampled infections.

Geospatial techniques, such as geoinformatics and advancements in computing and sensing infrastructure (e.g., cloud-based applications driven by big data), hold promise for sustainable disease control by facilitating efficient monitoring and reducing the reliance on broad-spectrum pesticides through targeted application in the field (Oerke, 2020). While visual observation by human experts remains the most common method for determining the spatial distribution of plant diseases and their pathogens in farmers' fields (Mahlein *et al.*, 2018), it is prone to errors, inconsistency, limited scalability, and inefficiency in evaluating a large number of plants over a wide area (Wu *et al.*, 2019). Aerial optical sensor platforms offer an attractive alternative for disease detection, as they enable the capture and analysis of data from extensive crop acreage using advanced analytical tools, thereby facilitating disease diagnosis and severity determination (Mahlein, 2016; Oerke, 2020).

Microbial consortia and biocontrol agents

A microbial consortium refers to a group of microorganisms withdifferent species that act together as a community (Shamarao *et al.*, 2021). It is well known that microbes possess the ability to control diseases, but achieving consistent results under field conditions has been a significant challenge (Trivedi *et al.*, 2017; Mitter *et al.*, 2019). However, due to the inconsistent performance of single-strain inoculants in disease control, the concept of utilizing a microbial consortium has emerged as a promising approach (Mitter *et al.*, 2019). Several successful examples of microbial consortia have been employed for managing plant diseases (Bradáèová *et al.*, 2019). For instance, Suryadi *et al.* (2013) utilized a microbial consortium consisting bacteria, which effectively controlled the soil-borne pathogens of rice under system for rice intensification (SRI).

Biocontrol products based on microbial agents provide safer alternatives to chemical products, leading to increased interest in the selection, characterization, and commercial development of biological control agents (BCAs) (Saravanakumar *et al.*, 2021). Several biocontrol agents, such as *Trichoderma* spp. and *Bacillus* spp., have demonstrated effectiveness against soil-borne pathogens like *R. Solani* (Chaudhary *et al.*, 2020).

Nanomaterials

Nanomaterials have emerged as a novel approach to the management of plant pathogens. These materials, characterized by their small size and unique properties, offer several advantages in controlling plant pathogens (Sharma *et al*., 2019). Studies have demonstrated the potential of nanomaterials in inhibiting the growth and activity of various soil-borne pathogens, including fungi, bacteria, and nematodes. Nanoparticles such as silver, zinc oxide, and copper oxide have shown antimicrobial properties, while nanocomposites and nanocarriers have been utilized for targeted delivery of biocontrol agents. The application of nanoparticles directly to soil, seeds, or leaves is a straightforward approach to protect plants against disease. However, it is crucial to consider the impact of nanoparticles on non-target species, particularly mineral-fixing/solubilizing bacteria, when applied to soil. In the management of soil-borne pathogens, researchers have explored the use of nanoencapsulation techniques to enhance antioxidant and antimicrobial functions. Cadena *et al*. (2018) highlight the importance of selecting the appropriate encapsulation form, considering both the safety of bioactive compounds and controlled release, while also assessing the potential effects of nanomaterials on human health and the environment.

Additionally, nanotechnology-based formulations have displayed enhanced stability, prolonged activity, and reduced environmental impact. Although the use of nanomaterials in agriculture is still in its early stages, further research is needed to fully understand their mechanisms of action, potential risks, and long-term effects on the environment and soil ecosystem. Nonetheless, nanomaterials hold promising prospects for the development of sustainable and effective strategies for managing soil-borne pathogens in agriculture.

Deciphering the Genetic diversity of plant pathogens

“Genetic diversity” describes the range of various genetic traits (alleles) within a population of organisms or a species. It is a key component of biodiversity and essential to a population or species’ long-term survival and adaptability (Mukhopadhyay and Bhattacharjee, 2016). A population’s gene pool stores genetic variety, when organisms reproduce, allele combinations that are made up of all the alleles in the population emerge. Genetic diversity has a significant impact on the evolutionary potential of pathogen populations. When genetic variation is reduced, it results in lower average fitness for populations and decreases their ability to adapt and persist over the long term.

Fisher’s fundamental theorem of natural selection underscores the importance of additive genetic variance in ecological and morphological traits related to fitness for a population’s ability to adapt to changing environments (Zhan and McDonald, 2005). Pathogen populations with higher levels of genetic diversity are expected to adapt more rapidly. Consequently, they can adjust more quickly to plant disease management strategies such as the use of agrochemicals, resistant plant varieties, and biocontrol agents. As a result, these diverse pathogen populations are more challenging to control. Allele frequencies measure genetic variation. Alleles are different versions of genes that can occupy the same locus on a chromosome. They provide insight into the genetic diversity of the population (Bernatchez, 2016). In population genetics, we typically take evolutionary processes that have an impact on pathogen populations into account. These forces include natural selection, gene flow, reproduction and mating systems, genetic drift, and mutation.

Populations should be at "Hardy-Weinberg equilibrium" in the absence of the impacts of mutation, genetic drift, gene flow, and selection. "Hardy-Weinberg equilibrium"- The (p2+2pq+q2) is a formula by "Wilhelm Weinberg" and "G. H. Hardy", is used to test how allele frequencies shift throughout generations in a population (Templeton, 2021). Plant pathogen genetic diversity arises from a complex interplay involving mutation, gene flow, recombination, random genetic drift, and natural selection. Genetic diversity of plant pathogens such as bacteria, fungi, viruses, and nematodes are critical for understanding and managing plant diseases. Phenotypic variation is caused by genetic variation. Population differentiation refers to variations in the frequencies of alleles (or nucleotides in sequence data) among subpopulations (Steenwyk *et al.*, 2016).

It can arise from a combination of factors such as random genetic drift and selection. When gene flow is limited, stochastic changes in allele frequencies among pathogen populations can lead to the random fixation of neutral genetic variations, resulting in nonadaptive genetic differentiation. Conversely, selection for traits related to the pathogen's ecology, like pathogenicity, aggressiveness, resistance to agrochemicals, temperature sensitivity, and reproductive success, can lead to adaptive genetic differentiation among genetically isolated pathogen populations.

Conclusion

Lots of researches are going on sustainable crop production, keeping in mind the targeted production as well as crop health and overall health of the whole biodiversity. Simply the causal organisms of plant diseases are not visible in naked eyes and it observed at a time when lot of damages are happened. Easy way of managing diseases is applying agro-chemicals. To avoid huge uses of agro-chemicals in rice diseases sustainable management practices is good option. Although remarkable breakthrough is not achieved but progress in some of the fields are really striking, particularly deciphering the genetic diversity of plant pathogens, precision agriculture, nanomaterials and application of microbial consortia.

References

Albahri, G., Alyamani, A. A., Badran, A., Hijazi, A., Nasser, M., Maresca, M. and Baydoun, E. 2023. Enhancing essential grains yield for sustainable food security and bio-safe agriculture through latest innovative approaches. *Agronomy* **13**(7): 1709.

Anastasiou, E., Fountas, S., Voulgaraki, M., Psiroukis, V., Koutsiaras, M., Kriezi, O., ... and Gómez-Barbero, M. 2023. Precision farming technologies for crop protection: A meta-analysis. *Smart Agricultural Technology* 5:100323.

Bernatchez, L. 2016. On the maintenance of genetic variation and adaptation to environmental change: considerations from population genomics in fishes. *Journal of Fish Biology* **89**(6): 2519-2556.

Bhatia, A., Chug, A. and Singh, A. P. 2021. Statistical analysis of machine learning techniques for predicting powdery mildew disease in tomato plants. *International Journal of Intelligent Engineering Informatics* **9**(1): 24-58.

Cadena, M. B., Preston, G. M., Van der Hoorn, R. A., Flanagan, N. A., Townley, H. E. and Thompson, I. P. 2018. Enhancing cinnamon essential oil activity by nanoparticle encapsulation to control seed pathogens. *Industrial Crops and Products* **124**: 755-764.

Chaudhary, S., Sagar, S., Lal, M., Tomar, A., Kumar, V. and Kumar, M. 2020. Biocontrol and growth enhancement potential of Trichoderma spp. against Rhizoctonia solani causing sheath blight disease in rice. *Journal of Environmental Biology* **41**(5): 1034-1045.

Francis, C. A. and Clegg, M. D. 2020. Crop rotations in sustainable production systems. (in) *Sustainable Agricultural Systems* (pp. 107-122). CRC Press.

Garibaldi, L. A., Gemmill-Herren, B., D'Annolfo, R., Graeub, B. E., Cunningham, S. A., & Breeze, T. D. 2017. Farming approaches for greater biodiversity, livelihoods, and food security. *Trends in Ecology & Evolution* **32**(1):68-80.

He, D. C., Burdon, J. J., Xie, L. H. and Jiasui, Z. H. A. N. 2021. Triple bottom-line consideration of sustainable plant disease management: From economic, sociological and ecological perspectives. *Journal of Integrative Agriculture* **20**(10): 2581-2591.

He, D. C., Ma, Y. L., Li, Z. Z., Zhong, C. S., Cheng, Z. B. and Zhan, J. 2021. Crop rotation enhances agricultural sustainability: from an empirical evaluation of eco-economic benefits in rice production. *Agriculture* **11**(2): 91.

Joshi, A. A., & Jadhav, B. D. 2016. Monitoring and controlling rice diseases using Image processing techniques. (in) 2016 *International Conference on Computing, Analytics and Security Trends* (CAST) (pp. 471-476). IEEE. 2016, December

Kumar, R., Mishra, J. S., Rao, K. K., Mondal, S., Hazra, K. K., Choudhary, J. S., ... and Bhatt, B. P. 2020. Crop rotation and tillage management options for sustainable intensification of rice-fallow agro-ecosystem in eastern India. *Scientific Reports* **10**(1):11146.

Kumar, S., Vishnoi, V. K., Kumar, P. and Dubey, R. C. 2023. Survival of Macrophominaphaseolina in plant tissues and soil. (in) *Macrophomina Phaseolina* (pp. 205-224). Academic Press.

Liu, Q., Zhao, Y., Li, T., Chen, L., Chen, Y. and Sui, P. 2023. Changes in soil microbial biomass, diversity, and activity with crop rotation in cropping systems: A global synthesis. *Applied Soil Ecology* **186**: 104815.

Manoharachary, C. and Kunwar, I. K. 2014. Host–pathogen interaction, plant diseases, disease management strategies, and future challenges. (in) *Future Challenges in Crop Protection Against Fungal Pathogens* (Goyal, A. and Manoharachary, C. eds) 185-229.

Mukhopadhyay, T. and Bhattacharjee, S. 2016. Genetic Diversity: Importance and Measurements. (in) *Conserving Biological Diversity: A Multiscaled Approach* (Mir, A.H. and Bhat, N. A. Eds) Research India Publications, New Delhi, 251-295.

Panth, M., Hassler, S. C. and Baysal-Gurel, F. 2020. Methods for management of soilborne diseases in crop production. *Agriculture* **10**(1): 16.

Revilla-Molina, I. M. 2009. Genetic diversity for sustainable rice blast management in China: adoption and impact. Wageningen University and Research.

Sandhu, H. 2021. Bottom-up transformation of agriculture and food systems. *Sustainability* **13**(4): 2171.

Sester, M., Raveloson, H., Tharreau, D. and Dusserre, J. 2014. Conservation agriculture cropping system to limit blast disease in upland rainfed rice. *Plant Pathology* **63**(2):373-381.

Sharma, D., Sharma, J., & Dhuriya, Y. K. 2019. (in) *Nanotechnology: A novel strategy against plant pathogens* (Panpatte, D. and Jhala, Y. eds). Nanotechnology for Agriculture: Crop production & protection 153-170. Springer, Singapore. https://doi.org/10.1007/978-981-32-9374-8_9

Steenwyk, J. L., Soghigian, J. S., Perfect, J. R. and Gibbons, J. G. 2016. Copy number variation contributes to cryptic genetic variation in outbreak lineages of Cryptococcus gattii from the North American Pacific Northwest. *BMC genomics* **17**: 1-13. https://doi.org/10.1186/s12864-016-3044-0

Suryadi, Y., Susilowati, D. N., Akhdiya, A., Kadir, T. S. and Wibowo, B. 2013. Efficacy of consortium bacteria for control rice diseases under system of rice intensification (SRI) in West Java-Indonesia. Albanian Journal of Agricultural Science **12**(1):143-147.

Templeton, A. R. 2021. (in) *Population genetics and microevolutionary theory*. John Wiley & Sons.

Vaglia, V., Bacenetti, J., Orlando, F., Alali, S., Bosso, E. and Bocchi, S. 2022. The environmental impacts of different organic rice management in Italy considering different productive scenarios. *Science of The Total Environment* **853**:158365.

Varsha, M., Poornima, B., & Kumar, P. (2022). A Machine Learning Technique for Rice Blast Disease Severity Prediction Using K-Means SMOTE Class Balancing. *International Journal of Risk and Contingency Management* (IJRCM) **11**(1): 1-27.

Xu, G., Sarkar, A. and Qian, L. 2021. Does organizational participation affect farmers' behavior in adopting the joint mechanism of pest and disease control? A study of Meixian County, Shaanxi Province. *Pest Management Science* **77**(3): 1428-1443.

Zhan, J. and McDonald, B. A. 2005. Analytical and experimental methods for estimating population genetic structure of fungi. *MYCOLOGY SERIES* **23**: 241.