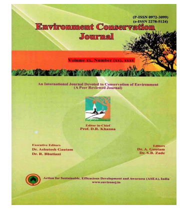
Environment Conservation Journal 23 (3):122-134, 2022



Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Agronomic practices for sustainable diseases management in rice: A review

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ARTICLE INFO

Received : 18 November 2021
Revised : 21 February 2022
Accepted : 01 March 2022

Available online: 29 May 2022

Key Words:
Agro-techniques
Disease management
Nutrients
Rice
food security

ABSTRACT

Rice is globally the most important food crop and there is a dire need to feed the ever-increasing population by improving its productivity. It has been realised that diseases are the major impediment towards enhancing the productivity of this crop. Despite the advent of modern effective disease control measures such as use of chemicals, bioagents and resistant varieties; agronomic practices still play a vital role in disease management in rice. Optimum use of different agro-techniques can be exploited for efficient control of various devastating diseases like rice blast, sheath blight, bakanae and many more by providing a favourable environment to better crop survival. Besides, appropriate selection of a variety, use of quality seed, method of establishment, planting time, nutrient, water and weed management practices can be well exploited to control various diseases. This manuscript entails to review the work pertaining to use of agronomic practices for exploiting the potential of crop environment interaction through reduced disease infection and to bridge the yield gap for ensuring sustained food security.

Introduction

Rice serves as the principal food crop for about 50% of the global population (Sain, 2020) and contributes to 50% of the calorie intake of the total population (Singh *et al.,* 2012). Globally rice crop occupies an area of about 160 mha with 495.07 mt of production and productivity of 4.54 t/ha. In India rice is grown over an area of about 43 mha with the production of about 112.9 mt (Pathak *et al.,* 2020). To sustain and meet the food and nutritional requirement of India, the requirement of rice is expected to go up to about 156 mt by 2030 (ICAR, 2010) with the 3 mt annual incremental rate in the current rice production (Dass *et al.,* 2016). Rice is cultivated over a wide range of environments owing to its wide range of adaptability, such as irrigated uplands, irrigated low land and rainfed uplands (Choudhary and Suri, 2014; Kaur *et al.,* 2015; Younas *et al.,* 2020). Though the productivity level varies among diverse growing environments, there are considerable constraints which hamper rice productivity. Among these, disease incidence is prominent, which alone reduces the yield by 21-

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Doi: https://doi.org/10.36953/ECJ.9742205

51% (Arya and Chander, 2012; Wangsawang *et al.,* 2019). The rice crop is infected by number of diseases right from the time seed is incubated, establishment of nursery and in the main field from transplanting up to the maturity expressing different types of symptoms (Figure 1). These diseases are seed, soil as well as air born with the variability in extent of damage (Table 1). Generally chemical measure is resorted for the control of these diseases; however, chemicals are posing serious threat to environment and human health. Additionally, resistant pathogenic strains have also been reported (Ohtani and Takeuchi, 2013; Sorbara and Pamer, 2019). Thus, to safe guard the environment and food security, the use of chemicals should be minimized (Damalas and Eleftherohorinos, 2011; Shah and Wu, 2019) and alternatives should be looked at. Hence it becomes imperative to control the disease by adopting those agronomic measures that serve dual purpose of controlling the disease and harness better yield without harming the environment. Manipulations in agronomic practices *viz*., sowing methods, time of sowing, nutrient management, water management and control of weeds have proven very effective in reducing the disease parameters of rice (Bhat *et al.,* 2013; Asibi *et al.,* 2019). These agro techniques have proven effective in controlling these diseases successfully by interrupting disease cycle of pathogen at any stage of crop by creating congenial environment to the crop. Response of rice diseases to agronomic manipulations has been discussed under the following headings.

Table 1: Extent of yield loss caused by different diseases in rice

Disease	Yield loss (%)	References
Rice blast	5-100	Dubey (1995); Musiime *et al.,* (2005); Wilson & Talbot (2009)
Bacterial leaf blight	2-74	Reddy *et al.,* (1978); Rajarajeswari & Muralidharan (2006)
Sheath blight	10-30	Xue-Wen *et al.,* (2008)
Brown spot	4-52	Chakrabarti (2001); Savaryet *et al.,* (2006); Barnwal *et al.,* (2013)
Rice false smut	0.2-49	Singh *et al.,* (1992); Biswas (2001)
Sheath rot	14-85	Sakthivel (2001); Singh & Raju (2012)
Bakanae	3-95	Hajra *et al.,* (1994); Singh & Sunder (2012)

Selection of variety

Selection of suitable variety for a particular agro-ecology is the most efficient and economical method to combat the diseases besides obtaining the higher yield. With the rice crop existing in three varietal types flourishing under appropriate agro-ecology. As Indica type of rice is suited to tropical areas of the world and these varieties of rice fail to mature at higher altitude of ≥ 1850 meters above mean sea level (amsl), while as Japonica varieties mature early in the plain belts and succumbs to blast disease. Thus, the varietal selection process in rice is an important step in reducing production risks caused by diseases. The varietal selection should be based on grain quality, maturity, fertilizer response, plant growth characteristics and resistance against major diseases. Varietal resistance is primary element of integrated disease management and is most acceptable method for farmers. For sustaining rice productivity, host resistance is an attractive and significant tool for controlling diseases in rice as it requires no additional cost to farmers and is also environmentally safe (Mew, 1991; Angeles-Shim *et al.,* 2020). However, due to the wide adoption of modern high yielding rice varieties, the traditional rice production system has been transformed into monoculture system which predisposes the varieties to loss the resistance over time. Thus, in addition to resistant varieties, agronomic practises play a vital role for disease management in rice. For example, panicle blast can be controlled by inter-planting rice varieties (Zhu *et al.,* 2000); infection can be escaped by using early maturing genotypes as compared to late maturing genotypes (Singh and Khan, 1989); avoiding use of semi-dwarf and photoperiod-insensitive cultivars as these are susceptible to sheath rot disease (Bigirimana *et al.,* 2015). In addition to these, multilines with different resistance genes can be used to control blast (Koizumi, 2001). Amongst virus diseases, rice tungro is found to be most destructive in rice growing areas. For this, BR8 and BRRI dhan37 has

Figure 1. Symptoms of major rice diseases: a) Rice blast b) Sheath blight c) Brown spot, d) False smut f) Bakanae g) Sheath rot

been found to have high recovery ability among upland and rainfed lowland areas, respectively (Khatun *et al.,* 2017). Recently, Rashid *et al.* (2019) have found Basmati 515 mm less prone as compared to Super Basmati.

Quality seed

Selection of quality seed is important determinant for crop health and the first step for obtaining healthy and robust seedlings for successful rice cultivation. More than thirty diseases of rice can be transmitted on or inside rice grains. Seed treatment is sound assurance against a number of diseases that damage early stands, reduce yields, and grain quality. Initially the seeds should be immersed in 2.5% salt solution for removing the chaffy, half-filled and diseased seeds, acting as potential carrier for seed borne diseases. Number of seed borne bacterial as well as fungal diseases have been reported to occur at nursery stage. Seed rot and seedling blight are complex disease caused by several seed-borne and soil-borne fungi and some bacteria including species of *Cochiobolus, Curvularia, Fusarium, Rhizoctonia*, *Sclerotium*, *Burkholderia glumae* and *B. plantarii* (Cartwright and Lee, 2001). Moreover, the major diseases of rice such as rice blast, sheath rot, brown spot, bakanae and bacterial leaf blight, are seed borne diseases. Thus, in order to produce high-quality nursery plants, it becomes essentially important to manage these diseases at seedling stage (Adhikari *et al.,* 2013) and for this, seed treatments with hot water and fungicides can prove to be effective against these pathogens. By immersing the seed material in hot water (60 °C) for 10 min has been relatively found effective in controlling several seed borne diseases in rice (Hayasaka *et al.,* 2001). More specifically, seed immersion in hot water (60 °C) for a period of 10-15 minutes was observed to kill *B. plantarii* effectively (Eguchi *et al.,* 2000), while soaking of seeds in water for 12 hours followed by exposure to hot water at 53°C eradicates the seed borne inoculum of *Xanthomonas oryzae* pv. *oryzae.* Since rice blast fungus is externally seed borne, hence seed treatment with fungicides or hot water eradicates the fungal inoculum from the seeds. Hot water treatment at 50 °C for 15 minutes was found effective in reducing rice blast incidence and severity (Faruq *et al.,* 2015; Hashim *et al.,* 2019). Similarly, for bakanae disease (*Gibberalla fujikuroi*) which causes yield losses of about 3.7-50% (Webster and Gunnell, 1992) can be controlled by fungicides (Ahangar *et al.,* 2012). Further, it has been reported that soaking of seeds into hot water at 60 °C for 10 minutes before sowing can significantly reduce the seed infections and bakanae incidence in nursery and fields conditions (Miyasaka *et al.,* 2000; Yamashita *et al.,* 2000).

Establishment method

A number of diseases have been observed to infect rice seedlings in the nursery stage, mostly being seed and soil borne. Most prevalent ones being seedling blight, or damping off and bakanae. Seedling blight has been observed to be more prevalent in early sown crop due to low temperature and damp soil. In addition, seedling blight and seed rot diseases are wide spread in soils with monoculture of rice, heavy rice residue, and minimum or reduced tillage. As compared to dry-seeded fields, water-seeded fields have more seedling diseases. In addition to these, planting depth also played an important role in disease severity. The management practice which tends to delay the emergence should be avoided for the favour of reducing seedling blight. Similarly, the type of blight in which cottony white mold growth is observed at the basal portion has been reported to be controlled by flooding the soil immediately after the visibility of symptoms. Moisture content in the nursery at the time of uprooting has been reported to influence the incidence of bakanae, a seed borne disease in nature. Sunder *et al.* (2014) observed significantly less incidence, where the nursery was uprooted in standing water as against the low water content in the nursery at the uprooting time.

Rice crop being established by different methods (direct seeding and transplanting) influencing the microclimate of the crop due to their varied canopy structure owing to the distance between the neighbouring plants which in turn influences the overall health of the crop. In direct seeded rice, planting density determined by number of plants per unit area tends to provide more shade and probably more humid microclimate in the canopy leading to more leaf-to-leaf contacts which ultimately favours rice disease epidemics (Savary *et al.,* 1998). Zhao *et al.* (2007) reported that high seed rate in rice harbours more disease infection by creating congenial environment for pathogen. Hence, the spatial distance between the plants plays a very crucial role in the dissemination of diseases which is highly influenced by the method of establishment. In direct seeded rice where there are more number of plants per unit area but the aggregation at plant level is slightly less as against transplanted rice, where there is more aggregation within each hill. This spatial difference between the plants is the reason for more incidence of disease in transplanted rice in comparison to direct seeded rice (Willocquet *et al.,* 2000). However, disease severity and incidence of blast (*Pyricularia oryzae*) were found to be less in transplanting compared to broadcasting method in rice (Reza *et al.,* 2011; Thoudam and Chhetry, 2017). With wider spacing of 22.5 cm in direct seeded rice, Rashid *et al.* (2019) observed maximum panicle length, kernels per panicle, paddy yield and harvest index with less incidence of bacterial leaf blight. Higher disease incidence and severity was reported in direct seeding than transplanted method by Iwuagwu *et al.* (2017) which then attributed to poor spacing and high population density conjointly producing high humidity suitable for fungal disease to perpetuate. Less diseases incidence has been reported in SRI system of rice cultivation against conventional method (Pathak *et al.,* 2012). Saremi and Farrokhi (2004) reported that transplanted rice plants display more symptoms of bakanae than those grown from broadcast seeds. On the contrary Kaur *et al.* (2015) reported sheath blight incidence did not vary significantly among different establishment methods.

Furthermore, variation in the crop geometry by altering the row spacing at the same planting density may influence the yield and incidence of sheath rot (*Sarocladium oryzae*) and false smut (*Ustilaginoidea virens*) in the rice crop (Kewat *et al.,* 2002). An optimum row spacing which has witnessed to reduced disease incidence is evident from the fact that sheath blight requires close foliar contact. Decrease in the incidence of sheath blight in skipped row planting (2:1) was observed by Rautaray (2007) owing to discontinuity in canopy, thus restricting the spread of disease. Skip row planting also proved to be beneficial in restricting the spread of sheath blight and sheath rot by restricting the spread of insect vectors *viz*., green leaf hoppers, *Nephotettix nigropictus and N. virescens,* and zigzag leaf hoppers, *Recilia dorsalis*). Closer spacing of 10 × 20 cm showed increase in the severity of bacterial leaf blight than at wider spacing (Meah, 1987). Shengfu *et al.* (2002) recorded less incidence of rice sheath blight was less when planted at 33.3 cm x 33.3 cm (58.4%) spacing or 40 cm x 40 cm (54.6%) spacing under SRI than that with traditional cultivation (70%). Similar results of more disease incidence at closer spacing of 15 cm x 15 cm in comparison to wider spacing of 20 cm x 25 cm was reported by Iwuagwu *et al.* (2017).

Planting time

Planting date-based strategies have been used successfully for management of various diseases, as it helps the plants by making better use of favourable environment at each growth stage favouring the escape from severe infection phase. Optimum sowing time helps in the controlling of tungro virus disease (Manwan, 1987). The sheath blight which is a very serious disease of rice has been observed to become more severe with increase in age of the plant. Minimum incidence of sheath blight was recorded, when rice was sown on July 15th (early sowing) as compared to on 30th June (Pal *et al.,* 2016). It has been reported that sheath blight resistance can be enhanced by square method of transplantation and sparse planting along with higher grain yields (Yang *et al.,* 2008). Sparse planting not only lowers the sheath blight occurrence but also enhanced the lodging resistance in rice (Sugiyama *et al.,* 2007). Blast infection in rice is a devastating disease which can cause up to 80% yield loss, depending up on factors like inoculum pressure, crop growth stage at infection, prevailing climatic conditions, varietal susceptibility and cultural practices (Groth, 2006; Prabhu *et al.,* 2006). In Sulawesi province of Indonesia, lowest leaf blast severity and neck blast incidence were recorded in 4th February transplanted crop than 22nd March and May 16th, due to the presence of less inoculum in early transplanted crop (Nasruddin and Amin, 2013). Iwuagwu *et al.* (2017) evaluated the effect of planting periods (Early June 15th, late June 30th, early July 15th and late July 30th) on disease incidence and severity in rice and observed least disease incidence in early sown crop. Similarly, Naklang *et al.* (1996); Laory *et al.* (2012) and Ahonsi *et al.* (2000) observed that disease incidence accelerates as the planting is done after optimum date. Singh *et al.* (2000) and Jha (2001) demonstrated that brown spot disease causes more damage in late sown rice crop. The infection with *Ustilaginoidea virens* the casual organism of rice false smut is favoured by high relative humidity, late sowing and high soil fertility (Narinder and Singh, 1989; Ahonsi *et al.,* 2000).

Nutrient management

Knowledge of the impact of nutrient management on the interaction of rice and disease serves the basic purpose of acquiring higher productivity (Luong *et al.,* 2003). The ability of plants to resist diseases has been attributed to better nutritional environment (Luong *et al.,* 2003). With this background, the farmers have been using nutrient management as one of the productive measures of disease management (Magdoff *et al.,* 2001).

Nutrients are not only vital for growth and development of the plants but also plays a significant role in the control of diseases (Agrios, 2005). There are a number of essential nutrients required by the plants for their optimum growth, development and resistance against biotic stresses. These nutrients help the plants to overcome the diseases either by improving the growth to optimum level, so that plant can tolerate the infection or by improving its ability to avoid the infection. The rapid growth in turn helps the plant to escape the most susceptible stage. Nutrients can affect the development of disease by influencing the physiology of plant or affecting pathogens or both (Dordas, 2008).

Nitrogen, phosphorus, potassium and silicon have been reported to influence the disease incidence in rice in number of ways depending upon different factors *viz*., form, quantity and interaction between host and pathogen. At higher dose of nitrogen, the proportion of young to mature tissue shifts towards later, which is more susceptible owing to more succulence and less suberin and lignin synthesis. Also, more amino acid accumulation in the leaf surface has been found to promote the germination and subsequent growth of conidia (Robinson and Hodges, 1981). Higher nitrogen rate has been reported to increase the blast severity (Kurschner *et al.,* 1992) by promoting the luxuriant crop growth, which resulted in increased relative humidity and leaf wetness of the crop canopy, thus favouring blast disease. In addition, higher rate of nitrogen is found to decrease the Si content, which then affects disease tolerance in plants. Time of nitrogen application also holds significance in reducing the effect of diseases. Leaf blast incidence and severity were significantly lower when nitrogen was applied in splits than its single dose application at normal or higher rate (Long *et al.,* 2000). Similar results of suppression of blast severity and most other foliage diseases in irrigated rice due to split application of nitrogen have been reported by Koraka (1965), Templeton *et al.* (1970), Amin and Venkataro (1979), Lee and Lee (1980), Bernaux (1981) and Kurschner *et al.* (1992). In contrast, application of full dose of nitrogen at panicle initiation stage in drought-prone upland conditions reduced the leaf and panicle blast as compared to its application at planting stage (Dos Santos, 1986). It is not only quantity and time of application but also the form of nitrogen, which affects the disease incidence. Nitrogen in the form of ammonium has been noticed to decrease the disease in case of *Pyricularia* spp. (Dordas, 2008). A reduced brown spot damage in rice was reported by Giudici *et al.* (1997) with extended period of drainage in mid-July along with late application of N + K and adjusting the planting date so that reproductive and ripening stage are not exposed to too high temperature. Rice false smut can be controlled in soils with low residual N, using low rate of N (Singh *et al.,* 1987).

Phosphorus (P) is the second most essential nutrient involved in metabolic process of the plant as well as pathogen (Dordas, 2008) and is vital for vigorous root formation which helps the plant to escape the disease (Huber and Graham, 1999). P fertilization in rice has been reported to reduce bacterial leaf blight and blast disease (Huber and Graham, 1999). Role of potassium is multifarious in terms of its pivotal role in various metabolic functions of plants and thereof in disease management. Potassium supply prevents disease incidence by initiating the development of thicker epidermal cells outer walls. It was observed that infestation intensity was closely related to the hardening of tissue and stomatal opening pattern (Marschner, 1995). Supply of potassium at sub optimum level is found to increase the accumulation of amides, a nutrient source for invading pathogen (Dordas, 2008) while its optimum level found to increase the resistance against the disease. Use of potassium has been reported to reduce the fungal incidence by 70 %, bacterial by 69 %, insects and mites by 63% and viruses by 41% (Perrenoud, 1990). It is not only sole application of potassium, but its ratio with other nutrients in the soil is also vital. Stem rot (*Helminthosporium sigmoideumas*) has been observed to occur at higher supply of nitrogen with low potassium level. Similarly inverse relationship was observed between the different diseases in rice *viz*, brown leaf spot (*Helminthosporium oryzae*), rice blast (*Piricularia oryzae*) and sheath blight (*Thanatephorus cucumeris*) and the supply of potassium, though the response was highly variable with the type of variety, with higher response imprinted by varieties possessing moderate degree of disease resistance (Hardter, 1997).

Silicon is known to provide the resistance to plants against infection at the minimum concentration of 3-5% at tissue level (Datnoff *et al.,* 1997), particularly in rice which is considered the Si accumulator with the ability to accumulate SiO_2 up to 10% (Liang *et al.,* 2006). It plays an unprecedented role for controlling fungal and bacterial diseases in rice. It seems that silicon helps to modulate lignin biosynthesis in rice by virtue of which it becomes resistant to fungal or bacterial attack (Song *et al.,* 2016). Silica after absorption is deposited in the cells and on cell walls, thus forming a strong barrier to halt the entry of hypha into the host, in addition it also helps in reducing the cell wall degradation enzymes secreted by fungi. Deposition of the Si on the cell walls affected the bacterial leaf blight development in rice (Song *et al.,* 2016). Silicon helps in the augmentation and accumulation of antifungal compounds like flavonoids, diterpenoids and phytoalexins which help in degrading fungal and bacterial cell walls (Brescht *et al.,* 2004). In rice adequate level of silicon has been witnessed to provide the resistance against diseases. Both brown spot disease (*Bipolaris oryzae*) and neck rot (*Pyricularia oryzae*) of rice were found to be severe in rice when the supply of silicon was inadequate (Datnoff *et al.,* 1997, 2001; Santos *et al.,* 2011). Similar results of increased susceptibility of rice to blast and other diseases has been attributed to the inadequate uptake of silicon (Kobayashi *et al.,* 2001; Rodrigues *et al.,* 2001; Massey and Hartley, 2006).

Zn is also known to possess the variable effect on disease incidence and severity in crops. This variable effect can be attributed to its impact on the availability of other nutrients. Zinc is known to reduce the leakage of low molecular weight compounds on account of free radical damage via detoxification of super oxide radicals (Simoglou and Dordas, 2006). Supply of Zn can lead to increase or decrease in disease severity in plants (Duffy, 2007). Moreira *et al.* (2013) observed a positive correlation between the elevated Zn concentration in leaves and its susceptibility to brown spot in rice. Though these effects of elevated levels of Zn were found selective. Increase in the dose of Zn application from 5 to 6 kg resulted in significant increase in disease infection of sheath blight and bacterial leaf blight as against false smut, sheath rot and brown spot (Singh *et al.,* 2012). Furthermore, Khaira disease, a non-pathogenic disorder, which is prevalent in low land condition mostly in Asian countries is found to be well managed by the foliar application of zinc sulphate (Nene, 1966).

Water management

Rice is sensitive to the shortage of water and is the highest water requiring crop in terms of water required to produce an economic product (5000L /kg rice). Irrigation affects both foliar and soil borne diseases (Rotem and Plati, 1969). It was observed that by altering the soil moisture content, disease incidence can be affected via its possible impact on soil/foliage biotic and abiotic processes. Air borne spores of *Pyricularia grisea* help in the spread of blast disease in rice. Maintaining the water level of >10 cm is recommended to curtail the disease (Tacker *et al.,* 2001). Similar results in tropical areas were noted by Lee *et al.* (2003) and IRRI (2010), as they found that blast incidence can be suppressed by flooding the soil as often as possible. Under water deficit condition brown spot (*Bipolaris oryzae*) has been reported to flare up for the lack of moisture. Furthermore, brown spot disease was observed to occur in susceptible plants when moisture was maintained below 50 cent bars. Das and Dath (1997) reported negative effects of crop submergence on the progress and development of sheath blight. However, in another study, it was reported that increase in sheath blight in flooded rice can be due to mobility of soil borne fungus in water (Stevens *et al.,* 2012). The greater incidence of bakanae disease of rice were observed in dry nurseries and summer crop than wet nurseries and spring crop as high temperatures and relatively humidity favours disease incidence.

Weed management

Weeds compete with the crop for both underground as well as above ground resources. Apart from competition, weeds pose greater threat of disease prevalence in the associated crop. This is because most of the weeds serve as alternate hosts for the disease-causing pathogen and also harbour pest vectors that migrate later to the crop. These alternate hosts play a vital role in providing the inoculum during the growing season. Thus, the weeding provides an effective measure for control of diseases through removal of alternate host. Sheath blight which is found to cause 7-50% yield reduction has been noticed in the fields, densely populated with weeds like *Echinochloa crusgalli*, *Echinochloa colonum* and *Cynodon dactylon.* The control of *Echinochloa* spp., which is alternate host of fungal pathogen leads to the less disease incidence of Sheath blight (Kaur *et al.,* 2015). Frequency of weeding (1st, 2nd and 3rd hand weeding) was found very ideal for avoiding incidence and severity of diseases (Mola *et al.,* 2015). Mohammadi and Amiri (2011) also found significant role of weeding on reducing disease incidence in rice crops. A number of weed species have been found to act as alternate hosts of most important diseases of rice, thereby helps in the development and survival of rice pathogens (Table 2).

Table 2: Important rice diseases and their alternate hosts

Disease	**Causal organism**	**Alternate host**	**References**
Rice blast	*Pyricularia Oryzae (Magnaporthe Grisea)*	*Carolina foxtail, Brachiaria mutica, Dinebra retroflexa, Leersia hexandra, Panicum repens*	Jia *et al.,* (2008)
Bacterial leaf blight	*Xanthomonas oryzae* pv. *Oryzae*	*Cyanodon dactylon, Cyperus rotundus, Leersia hexandra, Leersia oryzoides, Panicum repens, Paspalum dictum.*	Goto *et al.,* (1953); Gonzalez *et al.,* (1991); Noda & Yamamoto (2008)
Sheath blight	*Rhizoctonia solani*	*Pennisetumm americanum, Solanum tuberosum, Cynodon dactylon, Digitaria adscendus, Echinochloa crusgalli and Cyperus rotundus, C. difformis, Setaria glauca, Panicum repens, Brachiaria, Commelina oblique and Amaranthus viridis*	Chahal *et al.,* (2003)
Brown spot	*Bipolaris oryzae, Cochilobolus miyabeans*	*Cynodon dactylon, Digitaria sanguinalis, Echinochloa colona, Leersia hexandra, Pennisetum typhoides, Setaria italic, S. glauca, Imperata arundica, Panicum miliare, Saccharum officinarum, Zizania latifolia.*	Ou (1985); Biswal & Mohanty (1995); Sunder *et al.,* (2014)
Rice false smut	*Ustilaginoidea virens*	*Echinochloa crus-galli, Imperata cylindrical, Digitaria marginata*	Shetty and Shetty (1985); Atia (2004)
Sheath rot	*Sarocladium oryzae*	*Cyperus diformis*, *Echinochloa crusgalli*, *Monochoria vaginalis, Cyperus teneriffe, Hyrneachne assamica*, *Leersia hexandra*, *Panicum walense,* O*ryzae rufipogon*	Deka & Phookan (1992); Srinivasachary *et al.,* (2002)
Bakanae	*Fusarium moniliforme (Gibberella fujikuroi)*	*Vigna unguiculata, Panicum miliaceum, Echinochloa oryzoides, Echinochloa crus-galli*	Anderson & Webster (2005); Carter *et al.,* (2008)

Conclusion

In order to meet the future food demand of rapidly growing population, rice production and productivity needs to be increased, besides the rice cultivation should be done in sustainable way to reduce its environmental adversities. Diseases cause an average yield loss of about 15 to 30 percent annually to rice production and the excessive use of pesticides cause water pollution and human health hazards. These yield losses can be reduced significantly by using different agronomic practices on the pretext of congenial environment favoring the crop. However, the use of combination of agronomic practices with careful acquaintance of the crop environment interactions under variable agroecology becomes imperative for attainment of tangible outcome.

Conflict of interest

The authors declare that they have no conflict of interest.

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