STUDIES ON GRAIN DISCOLOURATION OF RICE (*Oryza sativa* L.)

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PALB 6082

DEPARTMENT OF PLANT PATHOLOGY

UNIVERSITY OF AGRICULTURAL SCIENCES

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Thesis submitted to the

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in partial fulfilment of the requirements

for the award of the degree of

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IN

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BENGALURU DECEMBER 2020

Affectionately Dedicated to

My Parents and Family

DEPARTMENT OF PLANT PATHOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU

CERTIFICATE

This is to certify that the thesis entitled **STUDIES ON GRAIN DISCOLOURATION OF RICE (*Oryza sativa* L.)** submitted in partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY IN PLANT PATHOLOGY** to the University of Agricultural Sciences, Bengaluru, is a record of *bona-fide* research work carried out by **Mr. BAPURADA POMPANA GOUDA, PALB 6082** during the period of his study in this University under my guidance and supervision. This thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

Bengaluru
December 2020

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STUDIES ON GRAIN DISCOLOURATION OF RICE (*Oryza sativa* L.)

BAPURADA POMPANA GOUDA

ABSTRACT

The 'Rice is life', a slogan most appropriate for our country as this crop plays a vital role in our national food security. Globally, India stands first in area (42.41 Mha) and second in rice production (166.5 Mt). This crop is associated with various diseases and among them the grain discolouration found to be a serious disease in India resulting huge yield loss and deteriorating quality of the seed. A roving survey conducted during *Kharif* 2017 and 2018 across three rice growing ecosystems of Karnataka, the highest mean per cent incidence of disease (15.21%) and severity (13.79%) was recorded in Hilly ecosystem followed by Coastal ecosystem (14.66%) and (13.35%); Tungabhadra & Upper Krishna Project (12.42% and 11.85%); Kabini & Kaveri (12.19% and 11.43%) and Thunga & Bhadra (11.54% and 10.62%). Mycoflora associated with discoloured grain samples were species of *Helminthosporium*, *Curvularia*, *Alternaria*, *Aspergillus*, *Fusarium*, *Cladosporium*, *Phoma*, *Trichoderma*, *Rhizopus* and *Magnaporthe oryzae.* They were isolated and identified based on morphology/spore characters. Among 38 rice genotypes screened during *Kharif* 2017 and 2018 under natural condition, none of them exhibited immune and resistance to grain discolouration. However, five genotypes viz., Jaya, BR-2655, Rajamudi, KCP-1 and Ratnachudi were found moderately resistant and twenty-one genotypes exhibited moderate susceptibility and remaining twelve genotypes showed susceptible réaction against grain discolouration. Biochemical studies revealed that phenol content in discoloured grains was significantly more that varied from 44.86 to 76.87 mg/g than in healthy grains (39.74 to 64.10mg/g) of all tested genotypes. Similarly reducing, non-reducing and total sugars recorded significantly high in diseased grains as compared to healthy grains. The spray of tebuconazole 50%+trifloxystrobin 25% 75WG @ 0.04% at panicle emergence was significantly superior in management of rice grain colouration with disease severity of 4.65%, grain yield of 53.09 q ha^{-1} with incremental benefit cost ratio of 1: 11.47.

December 2020

Department of Plant Pathology
UAS, GKVK, Bengaluru

T. NARENDRAPPA
(Major Advisor)

ಭತ್ತದ ಕಾಳುಗಳ ಬಣ್ಣ ಬದಲಾವಣೆಯ ರೋಗದ ಅಧ್ಯಯನ

ಬಾಪುರದ ಪೊಂಪನಗೌಡ

ಸಾರಾಂಶ

ನಮ್ಮ ರಾಷ್ಟ್ರೀಯ ಆಹಾರ ಭದ್ರತೆಯಲ್ಲಿ ಭತ್ತ ಪ್ರಮುಖ ಪಾತ್ರ ವಹಿಸುವುದರಿಂದ 'ಅಕ್ಕಿ ಜೀವನ'ಎಂಬ ಘೋಷಣೆ ನಮ್ಮ ದೇಶಕ್ಕೆ ಹೆಚ್ಚು ಸೂಕ್ತವಾಗಿದೆ. ಜಾಗತಿಕ ಮಟ್ಟದಲ್ಲಿ, ಭಾರತದ ಈ ಬೆಳೆಯ ವಿಸ್ತೀರ್ಣವು (42.41 ಮಿಲಿಯನ್ ಹೆಕ್ಟೇರ್) ಮೊದಲನೇ ಸ್ಥಾನದಲ್ಲಿದ್ದು ಮತ್ತು ಉತ್ಪಾದನೆಯಲ್ಲಿ (166.5 ದಶಲಕ್ಷ ಟನ್) ಎರಡನೇ ಸ್ಥಾನದಲ್ಲಿದೆ. ಇತರೆ ಬೆಳೆಗಳಂತೆ, ಈ ಬೆಳೆಯೂ ಸಹ ಬೆಳವಣಿಗೆಯ ಹಂತದಲ್ಲಿ ವಿವಿಧ ರೋಗಗಳಿಗೆ ತುತ್ತಾಗುತ್ತಿದ್ದು, ಅದರಲ್ಲೂ "ಕಾಳುಗಳ ಬಣ್ಣ ಬದಲಾವಣೆಯ ರೋಗ" ಅತೀ ಗಂಭೀರ ರೋಗವಾಗಿ ಕಾಣಿಸುತ್ತಿದ್ದು, ಇದರ ಪರಿಣಾಮ ಕಾಳುಗಳ ಗುಣಮಟ್ಟ ಕಡಿಮೆಯಾಗುವುದರೊಂದಿಗೆ ಇಳುವರಿಯೂ ಸಹ ಕುಂಠಿತವಾಗುತ್ತದೆ. ಈ ರೋಗದ ಸಂಭವ ಮತ್ತು ತೀವ್ರತೆ ಅರಿಯಲು 2017 ಮತ್ತು 2018 ಮುಂಗಾರು ಋತುಮಾನದಲ್ಲಿ ಕರ್ನಾಟಕದ ಭತ್ತ ಬೆಳೆಯುವ ಮೂರು ವಿವಿಧ ಪರಿಸರದಲ್ಲಿ ಕೈಗೊಂಡ ಸರ್ವೇಕ್ಷಣಾ ಅಧ್ಯಯನದಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು ರೋಗದ ಸಂಭವ (15.21 %) ಮತ್ತು ರೋಗದ ತೀವ್ರತೆ (13.79%) ಗುಡ್ಡಗಾಡು ಪರಿಸರದ ವ್ಯವಸ್ಥೆಯಲ್ಲಿ ತದನಂತರ ಕರಾವಳಿ ಪರಿಸರದಲ್ಲಿ ರೋಗದ ಸಂಭವ (14.66%) ಮತ್ತು ತೀವ್ರತೆ (13.35%) ದಾಖಲಾಗಿದೆ ಹಾಗೂ ನೀರಾವರಿ ಅಚ್ಚುಕಟ್ಟು ಪರಿಸರದ ಪ್ರದೇಶಗಳಾದ ತುಂಗಭದ್ರಾ ಮತ್ತು ಕೃಷ್ಣ ಮೇಲ್ದಂಡೆ ಯೋಜನೆಯ ಪರಿಸರದಲ್ಲಿ ರೋಗದ ಸಂಭವ (12.42%) ಮತ್ತು ತೀರ್ವತೆ (11.85%), ಕಬಿನಿ ಮತ್ತುಕಾವೇರಿ (12.19% ಮತ್ತು 11.43%) ಹಾಗೂ ತುಂಗಾ ಮತ್ತು ಭದ್ರ (11.54% ಮತ್ತು 10.62%) ದಾಖಲಾಗಿದೆ. ಭತ್ತದ ಬಣ್ಣ ಬದಲಾವಣೆಯ ರೋಗಕಾರಕಗಳನ್ನು ಪ್ರತ್ಯೇಕಿಸಿದ್ದು, ಇವುಗಳಲ್ಲಿ ಪ್ರಮುಖವಾದವುಗಳು ಹೆಲಮೆಂಥೋಸ್ಪೋರಿಯಂ, ಕರ್ವುಲೇರಿಯಾ, ಅಲ್ಟರ್‌ನೇರಿಯಾ, ಅಸ್ಪರ್‌ಜಿಲಸ್, ಪ್ಯುಸೇರಿಯಂ, ಕ್ಲಾಡೋಸ್ಪೋರಿಯಂ, ಪೋಮ ಹಾಗೂ ಟ್ರೈಕೋಡರ್ಮಾಗಳೆಂದು ಕಂಡುಬಂದಿದೆ.ಒಟ್ಟು 38 ವಿವಿಧ ಭತ್ತದ ಜಾತಿಯ ತಳಿಗಳನ್ನು 2017 ಮತ್ತು 2018 ಮುಂಗಾರು ಋತುಮಾನಗಳಲ್ಲಿ ಪರಿಶೀಲನೆಗೆ ಒಳಪಡಿಸಿದಾಗ, ಯಾವುದೇ ಭತ್ತದ ತಳಿಯ ಬಣ್ಣ ಬದಲಾವಣೆಯ ರೋಗಕ್ಕೆ ಪ್ರತಿರಕ್ಷಣಾ ಮತ್ತು ನಿರೋಧಕತೆಯನ್ನು ತೋರಿಸಲಿಲ್ಲ. ಆದರೆ, ಜಯ, ಬಿ.ಆರ್.–2655, ರಾಜಮುಡಿ, ಕೆ.ಸಿ.ಪಿ.–1 ಮತ್ತು ರತ್ನಾಚೂಡಿ ಭತ್ತದ ತಳಿಗಳು ಮಧ್ಯಮ ನಿರೋಧಕತೆ ತೋರಿಸಿದವು ಹಾಗೂ 21 ತಳಿಗಳು ಮಧ್ಯಮ ಪ್ರಭಾವಕ್ಕೆ ಒಳಗಾಗುವುದು ಮತ್ತು 12 ತಳಿಗಳು ಪ್ರಭಾವಕ್ಕೆ ಒಳಗಾದಂತೆ ತೋರಿಸಿದವು. ಭತ್ತದ ತಳಿಗಳಲ್ಲಿ ಪೀನಾಲ್ ಅಂಶ ಜೀವರಾಸಾಯನಿಕ ರೋಗವಿರುವ ಪ್ರತಿ ಗ್ರಾಂ ಭತ್ತದ ಕಾಳುಗಳಲ್ಲಿ 44.86 ಮಿ.ಲಿ.ಗ್ರಾಂ. ನಿಂದ 76.87 ಮಿ.ಲಿ.ಗ್ರಾಂ ಹಾಗೂ ಆರೋಗ್ಯವಿರುವ ಪ್ರತಿ ಗ್ರಾಂ ಭತ್ತದ ಕಾಳುಗಳಲ್ಲಿ 39.74 ಮಿ.ಲಿ. ಗ್ರಾಂ. ನಿಂದ 64.10 ಮಿ.ಲಿ.ಗ್ರಾಂ. ಕಂಡುಬಂದಿದೆ. ಹಾಗೆಯೇ, ಸಕ್ಕರೆ ಕಡಿಮೆಗೊಳಿಸುವಿಕೆ, ಸಕ್ಕರೆ ಕಡಿಮೆಯಾಗದಿರುವಿಕೆ ಮತ್ತು ಒಟ್ಟು ಸಕ್ಕರೆ ಪ್ರಮಾಣವನ್ನುಎಲ್ಲಾ ಪರೀಕ್ಷಿತ ಭತ್ತದ ತಳಿಗಳ ರೋಗಕಾರಕ ಕಾಳುಗಳಲ್ಲಿ ಹೋಲಿಸಿದಾಗ, ಆರೋಗ್ಯಕರ ಭತ್ತದ ಕಾಳುಗಳಲ್ಲಿ ಕಡಿಮೆ ಇರುವುದು ಕಂಡುಬಂದಿತು. ಭತ್ತ ಕಾಳುಗಳ ಬಣ್ಣ ಬದಲಾವಣೆಯ ರೋಗದ ನಿರ್ವಹಣೆಗೆ ಟೆಬ್ಯುಕೋನಜೋಲ್ 50% + ಟ್ರೈಫ್ಲಾಕ್ಸಿಸ್ಟ್ರೋಬಿನ್ 25% 75 ಡಬ್ಲೂ.ಜಿ. ಶೇಕಡ 0.04ರ ಸಿಂಪರಣೆಯನ್ನು ತೆನೆಗಳು ಹೊರ ಹಾಕುವ ಹಂತದಲ್ಲಿ ಸಿಂಪಡಿಸಿದಾಗ, ರೋಗದ ತೀವ್ರತೆ 4.65%, ಕಂಡುಬಂದಿದ್ದು, ಕಾಳುಗಳ ಇಳುವರಿಯು 53.09 ಕ್ವಿ./ಹೆ. ಹಾಗೂ ಹೆಚ್ಚಿರುವ ಲಾಭದ ಅನುಪಾತವು 1:11.47 ದಾಖಲಾಗಿದೆ.

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ಟಿ. ನರೇಂದ್ರಪ್ಪ
(ಮುಖ್ಯ ಸಲಹೆಗಾರರು)

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Symbols / Abbreviations		Details
%	:	Per cent
>	:	More than
a,i.,	:	Active ingredient
BOD	:	Biological oxygen demand
^{0}C	:	Degree Celsius
CD(P=0.05%)	:	Critical difference at 5 per cent level
CD(P=1%)	:	Critical difference at 10 per cent level
Cm	:	Centimetre
CRD	:	Complete Randomized Design
CV	:	Coefficient of variation
Dia	:	Diameter
et al.,	:	and other co-workers
Fig.	:	Figure
G	:	Gram (s)
gl $^{-1}$	:	Gram per litre
i.e.	:	that is
ISTA	:	International Seed Testing Association
Kg	:	Kilogram
Kg ha^{-1}	:	Kilogram per hectare
q ha^{-1}	:	Quintal per hectare
M	:	Metre
m^2	:	Metre square
Mg	:	Milligram
mg g^{-1}	:	Milligram per gram
Min.	:	Minute
ml	:	Millilitre

Symbols / Abbreviations		Details
Mt	:	Million tones
N	:	Normality
nm	:	Nanometre
No./no.	:	Number
PDA	:	Potato Dextrose Agar
P^H	:	Potentiality of H^+ ion concentration
ppm	:	Parts per million
psi	:	Pounds per square inch
Sec	:	Second
SEM	:	Standard Error of Mean
sp. spp.	:	Species (Singular or Plural)
t	:	Tonnes
µg	:	Micrograms
µg ml^{-1}	:	Microgram per millilitre
viz.,	:	Namely
Mha	:	Million hectares
% CV	:	Per cent of Co-efficient of variation
Mt	:	Metric tonne
/	:	Per, also means and or
G	:	Granule
EC	:	Emulsifiable Concentration
WP	:	Wettable Powder
WG	:	Wettable granules
Sl.no.	:	Serial Number
mb	:	Milled basis
PDI	:	Percent Disease Index

I INTRODUCTION

About half of the world population consuming rice as their staple food (IRRI, 2006) and cultivation of rice have its impact on livelihoods and financial position of citizens of countries. Cultivation of rice can be seen in majority of tropical and subtropical regions across the globe. Globally, rice is produced in 167 million hectares with a production of 759.9 million tonnes (milled rice 503.9 million tonnes), (FAO, 2018). Whereas, Asia housing 60 per cent world population is largest (more than 90 per cent) producer and consumer of rice globally. Three billion Asians get their 35-60 percent of caloric requirement by consuming rice (Guyer *et al*., 1998).

India has a long history of rice cultivation. Globally, it stands second in rice production (166.5 million tonnes) after China even though occupies first position area under cultivation (42.41 million hectares) (FAO, 2018). It contributes 21.6 per cent to global rice production. With in the country, rice occupies one quarter of total area under crops and contributes significantly to total food grain production (40 to 43%) and thereby play a pivotal role in national food and livelihood security. Total area under rice in Karnataka is 1.42 million hectare with a production of 3.6 million tonnes accounting a productivity of 2.62 tonnes per hectare (FAO, 2018).

The factors responsible for reduction in productivity of rice include biotic (pests and diseases) and abiotic stresses. Among biotic stresses, plant diseases *viz.*, blast, brown spot, bacterial bight, sheath rot and sheath blight *etc*., are distributed widely and known to cause an economic crop loss. Hence, these diseases have drawn attention of researchers which lead to intensive studies across the world. However, other diseases on which sufficient stress is not yet devoted are generally considered as “minor disease” and not have been studied intensively. Henceforth, rice grain discolouration has been focused.

Rice grain discolouration is distributed throughout major rice growing areas across the world. Earlier, it was treated as minor disease due to less occurrence but recently drawn attention in tropical rice growing region due to its increased severity of incidence (Narain, 1992). Grain discolouration disease is reported from rice growing

regions of Asia, Africa and America. In India, the rice crop is usually exposed to more humid and warm growing condition, especially during panicle and maturity stages. Growing of early and medium duration cultivars of rice during rainy season significantly favours the incidence of grain discolouration.

Rice crop is prone to be infected by more than 76 types of pathogens like fungi, bacteria and viruses causing various diseases in the field. Fungi belonging to different taxonomic groups, mainly *Ascomycetes* and *mitosporic* fungi such as *Fusarium, Cladosporium, Cochliobolous,Colletotrichum, Alternaria* and *Diplodia,* have been reported to infect grains and legumes of rice in standing crop and seeds or grains and glumes under high moisture storage condition (24-25%) leading to severe incidence of grain discolouration disease (Saini *et al.,* 2012).

Grain discolouration of rice is regarded as a complex disease due involvement multiple microorganisms separately either on glumes or kernels or both. The fungi known to be associated with discolouration of rice grains are *Botrytis oryzae, Alternaria padwickii, Pyricularia oryzae, Fusarium moniliforme, Fusarium graminearum, Nigrospora oryzae, Curvularia* spp*, Dichotomophthoropsis nymphacearum, Epicoccum nigrum, Phoma sorghina* and *Heterosporium echinunulatum etc*. As reported by Ou in 1985, mainly fungi belonging to two groups have been associated with incidence of grain discolouration of rice. The field fungi, predominantly parasites and infects grains before harvest are *Helminthosporium oryzae, Alternaria* sp., *Curvularia* sp., *Epicoccum* sp., *Fusarium moniliforme, Nigrospara* sp., *Pyricularia oryzae, Phoma* sp. and *Sarocladium* sp. *etc*. Whereas, other group of fungi comprising storage moulds and saprophytic fungi observed developing after harvest such as Aspergillus, *Penicillium*, *Mucor*, *Rhizopus etc*. These pathogens were found colonizing with discoloured grains (Khan *et al*., 1988 and Javaid *et al*., 2002).

From the previous studies, it has been documented that seed borne inoculums of *Alternaria alternata* were main cause for ashy grey discolouration, whereas *Helminthosporium oryza e*mainly responsible for black discolouration and dark brown spot found on either seed coat or endosperm of discoloured seed, whereas *Curvularia*

geneculata (*Cochiobolus geniculatus*) caused eye shaped spot (Ou, 1985). In addition, *Fusarium equiseti, Fusarium oxysporum (Gibberella zeae)* and *Fusarim moniliformae* (*Gibberella fusicoli*) were mainly leading to pink discolouration and *Sarocladium oryzae* was responsible for light brown discolouration on seed coat, endosperm and embryo of discoloured seed. The fungi reported colonized with discolouration of grains are *Alternaria padwickii, Alternaria alternata, Bipolaris oryzae*, *Curvularia lunata, Dichotomophthoropsis nymphacearum Epicoccum nigrum, Fusarium moniliforme, Fusarium graminearum, Nigrospora oryzae, Pyricularia oryzae, Phoma sorghina,* and *Heterosporium echinunulatum etc.* (Sumangala and Patil, 2009).

Grain discolouration usually leads to poor quality of grain or seed and as an important degrading factor. In such seed's disorders might be observed as presence of seed borne pathogens (Padmanabhan, 1974).

A significant variation was detected in biochemical constituents between the healthy and diseased rice grains. There was a variation in biochemical constituents within a variety also. When compared with healthy grains, concentrations of phenol, protein, total sugar and amino acid were high in discoloured grains (Kheroda Devi *et al.,* 2004).

Control of majority of seed borne diseases has been reasonably achieved by using systemic fungicides, non systemic fungicides and biological agents. Although, fungicides have been successful, they are always associated with hazards involved in handling, environmental pollution including chances of toxicity entering into the growing plant and later into the food chain. In recent years, the concept of food quality itself has been changed dramatically. Now it is not only refers to visual characteristics of the final product, it also includes the way product is produced, processed and transported. As the health consciousness among the consumers has been increasing, especially in developed and developing countries they have started spending to buy natural food materials. This is because of increasing awareness about use of synthetic chemical fertilizers and disease control inputs in agriculture not only affecting the natural resources and soil fertility adversely but also affecting the health of human beings. This gravity of depleting soil health and environmental hazards was able to draw the attention of scientists and policy

makers to find out a way for sustainable and eco-friendly farming system in various agro climatic conditions worldwide keeping in view the need of present and future generations. Hence the study has focused on the identification of grain discolouration resistant genotypes for cultivation in endemic areas helps to minimize the losses due to this disease and also to avoid the pollution caused by chemical fungicides.

Keeping all the above issues in view, the present investigation on grain discolouration of rice was carried-out with the following objectives.

1. Survey to assess the severity of grain discolouration in different rice ecosystems of Karnataka.
2. Isolation and identification of pathogens associated with grain discolouration.
3. Screening of genotypes for reaction to grain discolouration of rice.
4. Effect of grain discolouration on biochemical constituents of rice.
5. Management of grain discolouration in rice through chemicals and bio-agents.

II REVIEW OF LITERATURE

Grain discolouration of rice has been found to be a serious disease in India and other rice growing countries in the world resulting in huge loss in both yield and quality of the seed and thereby deteriorating the commercial value and nutritional value of the crop. Grain discolouration of rice is emerging and spreading fast in rice cultivating areas of Karnataka. An attempt has been made to document the review various studies conducted earlier on grain discolouration of rice.

2.1 Survey and surveillance of grain discolouration in different rice ecosystems

Rice grain discolouration affects the quality of grain and is an important devastating factor in reduced yield (Baladcci and Picco 1948, Misra and Vir, 1991). Roving survey was conducted during 1989 and 1990 in rice growing areas of the districts of Chamba, Solon, Una, Sirmour, Kangra, Chamba, Hamirpura. Mandi and Kullu in Himachal Pradesh. The different cultivars were assessed on rice grain discolouration and reported the maximum grain discolouration at Rahlu in Kangra district (88.12 %) and least was in Una (7.60 %). In research studies higher grain discolouration was observed in PR-106 (23%) than in IR (19%) (Sharma *et al.* 1987, Sharma and Vaid, 1990).

Castano *et al.* (1991) studied the rice grain discolouration in Himachal Pradesh and reported that *Alternaria alternata* association was maximum to an extent of 46.00 % in the Kullu followed by Bilaspur 28.00%. Whereas, the frequency of *Curvularia lunata* was maximum in Kangra to an extent of 21.50%. They also observed *Pestalotiaoryzae* incidence to an extent of 21.50% from Bilaspur.

The pathogen colonization with rice cultivar *viz. Curvualaria lunata* was highest in TN-1 (27.5%) followed by IR-50 (25.0%) IET-6666 (22.5%) and lowest in Mashuri (7.5%), whereas *Fusarium moniliforme* was highest in IET-6666 and Mahsuri (25.0 %) and lowest in IR-50 (15.0%). Per cent occurrence of *Trichoderma padwickii* ranged from 7.5 to 15.00, whereas association of all other fungi used in the experiment was low. However, *Fusarium* spp. found constantly associated with all the cultivars tested and incidence ranged from 22.5 percent to 25.00 percent (Ali and Deka 1996). A survey was

conducted during 2001 in Brazil and reported the associated pathogens with discoloured grains of rice grown in irrigated areas as *Aspergillus* spp. (76.00%), *Pencillium* spp. (34.30%), *Nigrospora oryzae* (16.30%), *Phoma* spp. (11.10%), *Trichoderma padwickii* (8.40 %), *Alternaria* spp. (6.30%) and *Fusarium* spp. (1.80 %) (Franco *et al.* 2001).

Van Du *et al*. (2001) surveyed on discoloured grains of 12 rice genotypes collected from Long An province and observed that there were nine fungal species with varied detection frequencies *viz*., *Curvularia* spp. (13.44%), *Alternaria padwickii* (12.00%), *Bipolaris oryzae* (4.90%), *Sarocladium oryzae* (1.90%), *Fusarium graminarium* (1.50%), *Tilletiabarclayana* (0.16%), *Phoma sorghina* (0.10%), *Cephalosporium oryzae* (0.34 %) and *Ustilaginoidea virens* (0.05%).

Negi and Das (2003) documented that light brown, brown and dark brown dot like spots was most pronounced with variety Narendra- Negi (54.70 %), Manhar (46.60 %), Saket (45.30 %) and Pant Dhan-16 (40.30 %) which was caused by *Bipolaris oryzae*, while *Curvularia lunata* was recorded with Narendra-80 (44.30 %) and Indrasan (36.80%), *Fusarium. graminearum* was associated with Manhar (40.30 %), PantDhan-16 (39.90 %) and Saket-4(30.80 %), *Fusarium moniliforme* associated with Narendra 259 (47.40%) and Basmati 385 (45.40%). The highest incidence of grain discolouration noticed in Basmati-385 (36.80%) and this was followed by Pant Sugandha, Dhan-15 (30.20%), Basmati- 386 (29.40%) and Taroaori Basmati (25.80 %).

They reported the association of seed borne fungi *viz.*,*Bipolaris oryzae, Curvularia lunata, Fusarium oxysporum, Fusarium moniliforme, Alternaria tenuis, Aspergillus niger,Chaetomium globosum, Aspergillus flavus, Aspergillus terreus* and *Penicillium* sp. from seeds of three rice genotypes like Faro 12, Faro 15 and Faro 29 in storage and *Fusarium oxysporum, Bipolaris oryzae, Curvularia lunata, Fusarium moniliforme, Trichoderma harzianum* and *Chaetomium globosum* from the field in Nigeria. *Fusarium moniliforme* which more commonly found both in the field and storage (Ibiam *et al*. 2008).

Imran Arshad *et al.* (2009) reported that grain discolouration disease of rice a serious threat to rice crop and the pathogens *viz.*, *Drechslera oryzae, Bipolaris oryzae, Alternaria alternata, Alternaria padwickii, Fusarium moniliforme, Aspergillus niger, Curvularia oryzae* and *Nigrospora oryzae* were associated with rice panicles infested with grain discolouration samples were collected from rice growing areas of Sheikhupura, Pirmahal, Vehari and Faisalabad districts in Pakistan.

Gopalakrishnan *et al*. (2010) surveyed totally 287 seed samples comprising of 20 genotypes obtained from various parts of Tamil Nadu and healthy status of grains were studied. Totally eight genera of fungi *viz*., *Bipolaris,Alternaria, Fusarium, Curvularia, Aspergillus, Sarocladium,Chaetomium* and *Trichoderma* comprising twelve species were found to be associated with the seed samples. Among them, the most predominant one was *Bipolaris oryzae* which was associated with (58.89%) seed samples, followed by *Alternaria padwickii* (52.96%), *Curvularia* (44.60%), *Alternaria tenuis* (37.63%) and *Sarocladium oryzae* (26.83%).

To know the incidence and severity of grain discolouration of rice, a roving survey was conducted during 2006 and 2007 in farmers fields of Gulbarga, Raichur and Koppal districts by Sumangala *et al.* (2010). During the year 2006 and 2007, the mean incidence of disease (11.22%) and severity (10.11%) were observed in Koppal district. Whereas, in Raichur district, it was recorded with mean disease incidence of 9.90 % and disease index of 9.01%. In Gulbarga district, the disease incidence was 9.04 % with disease index of 9.01 %. Ahmed *et al*. (2013) categorized the seed as apparently healthy (61.50-79.05 %), spotted (6.14-12.80 %), discoloured (4.81-14.35 %), deformed (2.00-7.55 %), varietal mixtures (2.20-8.80%) and chaffy grains (0.95-6.4 0%) from three rice genotypes.

In Raipur, extent of grain discolouration varied from with variety to variety. Kranti (32.95%) has recorded maximum amount of discoloured seed and was succeeded by IR-36 (30.36%), Mahamaya (29.56%) and Swarna (29.39%) while the highest chaffyness was observed in HMT (20.82%), IR-36 (19.63%) and Pant-4 (19.33%) (Bodalkar and Awadhiya, 2014).

Kakoly*et al.* (2014) reported (20.55 to 70.55%) of apparently healthy seeds, (0.70 to 10.55%) of discoloured seeds and (1.40 to 42.35%) of spotted seeds from the seed material pertaining to eight land races.

2.2 Pathogen(s) associated with grain discolouration

In USA, totally isolated sixteen fungal genera from discoloured rice grains namely *Curvularia lunata, Fusarium* spp.*, Trichoconis caudata, Helminthosporium oryzae, Phoma*spp.*, Alternaria* spp.*, Cladosporium herbarum, Nigrospora oryzae, Epicoccum neglectum* and *Helicoceras oryzae* (Tullis, 1936). Padmanabhan *et al*. (1949) isolated mycoflora namely *Curvularia lunata, Drechslera oryzae, Fusarium moniliforme, Sarocladium oryzae, Trichoconis padwickii, Nigrospora oryzae* and *Cercospora oyzae* from the discoloured grains and resulting in reduced germination rate.

Johnston (1958) examined the seed lot and infected discoloured grains with *Fusarium* spp. (14.6%) *Drechslera oryzae* (9.2 %), *Alternaria padwickii* (7.9 %) and others were *Curvularia* sp. and *Aspergillus penicillium.*

Iizuka (1958) reported the species of *Aspergillus*, *Penicillium* and *Streptomyces were* isolated from discoloured rice grains samples were collected from Burma and Thailandand germination was adversely affected. They found that *Curvularia* spp., *Fusarium* spp., *Helminthosporium oryzae, Alternaria tenuis*, *Nigrospora oryzae*. and *Pyricularia oryzae* were commonly encountered with seed samples of paddy (Neergard and Saad, 1962).

Pandey *et al*. (1982) isolated six fungal species *viz*., *Alternaria alternate, Aspergillus flavus, Aspergillus niger, Epicoccum purpurascens Cladosprium cladosporioides* and *Penicillium granulatum* isolated from seed of *Setaria italica*. It was observed that seed germination of *S. italica* were reduced by fungal metabolites of *E. purpurascens* (62.16 %) followed by *Cladosprium cladosporioides* (37.19 %) *Aspergillus flavus* (35.84 %), *Aspergillus niger* (33.74 %), *Alternaria alternata* (32.74 %) and *Penicillium granulatum* (28.42 %).

Sharma and Chaudhary (1986) isolated total 34 fungi from23 discoloured rice seed samples which includes *Fusarium* spp., *Curvularia* spp., *Drechslera oryzae*, *Aspergillus* spp. and *Rhizopus* spp.

Sharma *et al*. (1987) isolated colonized pathogens from discoloured rice grains *viz.*, *Fusarium moniliforme, Curvularia lunata, Alternaria alternata* and *Trichoconis padwickii.* Intensity of discolouration was more due to *Fusarium moniliforme* as compared to other pathogens. Misra and Vir (1988) detected fungi causing discolouration of rice seed as *Fusarium solani*, *Fusarium moniliforme* (*Gibberella fujkuroi*), *Fusarium equiseti*, *Pyricuraliaoryzae*, *Epicoccum purpurascens* (*E. nigrum*), *Sarocladium oryzae*, *Alternaria padwickii*, *Alternaria alternata Sclerotium oryzae* and *Cladosporium cladosporioides*. According to Agarwal *et al*. (1989) reported that majority of fungi namely, *Curvularia lunata, Helminthosporium oryzae, Alternaria alternata, Fusarium moniliforme, Nigrospora oryzae, Sacrocladium oryzae* and *Trichoconis padwicki i*responsible for causing grain discolouration.

Khan *et al.* (1988) isolated eight pathogens namely *Drechslera oryzae, Bipolaris oryzae, Fusarium moniliforme, Alternaria alternata, Alternaria padwickii, Nigrospora oryzae, Curvularia oryzae* and *Aspergillus niger* from diseased samples collected from rice growing areas of Samundri, Sheikhupura, Faisalabad, Vehari and Pirmahal in Pakistan.

Ahmed *et al.* (1989) collected three rice genotypes *viz.* Pajam, Joya and BR6 (Local) from Feni district in Bangladesh and studied the seed health and quality by dry inspection and blotter tests. In case of Pajam variety, the samples contained 63.17 to 79.00 per cent apparently healthy seeds 7.15 to 10.45 per cent spotted seeds, 5.80 to 10.25 per cent discoloured seeds, 2.95 to 7.35 per cent deformed seeds, 2.75 to 8.80 per cent varietal mixtures and 1.25 to 5.34 per cent chaffy grains, whereas healthy seeds ranged from 66.70 to 71.50 per cent. Seed samples contained 8.68 to12.90 per cent spotted seeds 5.70 to10.78 per cent discoloured seeds, 2.00 to 6.95 per cent deformed seeds, 2.30 to 9.90 per cent varietal mixtures and 1.89 to 4.55 per cent chaffy grains.

They reported that fungi associated with grain discolouration were *Helminthosporium oryzae* and *Curvularia affinis* which resulted in stunted growth of seedlings.

Misra and Vir (1991) recorded losses in 1000 grain weight of 66 rice genotypes and also found that losses in weight were 42.2 and 51.2 per cent, respectively in seed lot having less than 49 per cent discoloured seeds and having more than 51 per cent discoloured seed, respectively compared with healthy and seeds having no discolouration.

Ali and Deka (1996) isolated ten fungal species like *Drechslera*, *Curvularia*, *Fusarium*, *Aspergillus, Penicillium, Nigrospora*, and *Trichothecium* from discoloured grain of six rice genotypes. Among field fungi, the *Fusarium moniliformae was* showed highest frequency. *Aspergillus* and *Penicillium* spp. were showed lesser frequency among storage fungi.

Babo and Lokesh (1996) collected discoloured grain samples of various genotypes of rice from diversity agro-climatic regions of Karnataka and examined the seed-borne fungi under *invitro*. Recorded twenty-four fungal species, of which *Fusarium moniliforme*, *Aspergillus* sp. *Drechslera* sp. *Chaetomium globosum*, *Rhizopus sp.and Verticillium* sp.and were frequently colonized with rice seeds.

Sinha (1999) reported highest incidence of seed discolouration in the rice cultivar TN-1 (66%) followed by Manhar (62.8%) and Jaya (58.75%). He also observed that the increase in degree of discolouration leads to reduction of grain weight.

Pandey *et al*. (2000) recorded mycoflora from seeds of hybrid rice *Drechslera australiensis,Curvularia oryzae, Curvularia lunatus, Gibberelea fujikuroi, Alternaria padwickii, Cochliobolus miyabeanus, Fusarium palidoroseum, Magnaporthe grisea*, *Curvularia ovoides, Nigrospora oryzae, Sarocladium oryzae* and*Mangnaporthe salvini*. Prakash and Rao (2001) reported six fungi colonized with discoloured grain namely *Curvularia lunata, Cochliobolus miyabeanus, Sarocladium oryzae, Gibberellazeae, Gibberella fujikuroi* and *Alternaria* sp. The maximum infestation in all rice genotypes was caused by *Sarocladium oryzae.*

Negi and Das (2003) studied the effect of grain discolouration, the associated mycoflora were *Bipolaris oryzae, Curvularia lunata, Fusarium graminearum* and *F. moniliforme* and they also observed pink to light brown discolouration caused by *F. moniliforme* which was also caused the highest number of abnormal seedlings.

Reddy *et al*. (2004) reported *Aspergilli* (*Aspergillus niger, Aspergillus flavus and Aspergillus ochraceus*) infection of paddy samples procured from different rice growing areas in India. They included *Aspergillus flavus* showing two distinct types, one having parrot green and other olive green colony.Chauhan *et al*. (2005) studied the rice discoloured seeds colonized with several pathogenic and saprophytic fungus *viz., Fusarium* sp., *Sarocladium* sp., *Pyricularia* sp., *Curvularia* sp., *Alternaria* sp., *Phyllostietam* sp., *Penicillium* sp., *Diplodia* sp. and *Aspergillus* sp.

Samira *et al*. (2005) observed two types of fungi, one with true rice pathogens: *Heliminthosporium oryzae, Curvularia lunata, Pyricularia grisea, Heliminthosporium spiciferum, Heliminthosporium satium* and *Heliminthosporium australiensis,* second with saprophytes that caused rice discolouration *viz*., *Alternaria alternata, Fusarium moniliforme, Trichoderma harzianum, Nigrospora oryzae, Trichothecium roseum* and *Cladosporium herbarum*. The observed the dominance of *Curvularia lunata* (23.67%), *Fusarium moniliforme* (18.57%) *Fusarium* sp*., Drechslera oryzae, Penicillium* sp*., Trichoconis padwickii, Nigrospora*sp. and *Cercospora ragrostidis* (Tripathi and Jain (2005).

Haque *et al.* (2007) investigated the germination, seedling vigour, seed health and associated pathogens of rice seeds produced by trained and untrained farmers. Physical sorting, blotter test, dry inspection, germination test by paper towel method and seedling vigour tests were performed. Maximum pure seed (98.01%) was found in seed samples of trained farmers than untrained farmers (95.19 %). Healthy seed of (68.70 %) were recorded in seed samples of trained farmer's and (49.41 %) in untrained farmer's samples. Four fungal genera were *Fusarium, Aspergillus, Penicillium,* and *Curvularia* associated with the rice seed samples stored from six months. In case of freshly harvested rice seed, trained farmers samples yielded the lowest count of *Bipolaris oryzae* (2.9%), *Fusarium*

sp. (2.6%), *and Nigrospora oryzae* (1.6%). *Curvularia* sp. (0.9%) and *Alternaria padwickii* (0.3%). Seeds of trained farmers gave maximum germination (82.5%) and also yielded maximum number of healthy seedlings (77.6%). The seeds of untrained farmers had very low germination (63.2%), highest number of diseased (6.98%), abnormal seedlings (6.85 %) and lowest number of normal seedlings (48.6%). Root length shoot and root weight of trained farmers seedlings were higher than untrained farmers.

Mandhare *et al.* (2008) studied 14 paddy genotypes *viz.,* Basmati-370, Ambemohar, HMT-Sona, Karjat-2, Pawana, Jaya, Garvi kolpi-248, Ratna, Palghar, Phuleradha, Karjat-3, Indrayani, Masuri, RP-4-14 Phulemaval, Bhogawati and R-24 by using standard blotter method and detected seven different organisms and five recorded as pathogenic to paddy. They were *Curvularia lunata, Drechslera oryzae, Fusarium oxysporum, Alternaria padwickii* and *Fusarium moniliformae.* The lowest mycoflora was recorded in Palghar (4 %) with 97 % seed germination, whereas the highest mycoflora (20%) was recorded in Indrayani with 80 per cent seed germination.

Wen Huang *et al.* (2010) observed four fungal pathogens on infected grains *viz.*, *Bipolaris australiensis, Curvularia lunata, Alternaria tenuis* and *Fusarium proliferatum* and also studied biological, morphological, and molecular characterization of these pathogens.

Butt *et al.* (2011) studied five genotypes of rice *viz*. Basmati-385, KS-282, Basmati Kernal, Basmati-198 and Basmati-370 to investigate the presence of seed-borne mycoflora using blotter paper method. They found associated with Basmati kernel (27 %,), Basmati-385 (19 %), Basmati-370 (17 %), Basmati-198 (16 %) and KS-282 (14%). Four fungal species namely *Alternaria* sp.,*Helminthosporium* sp., *Fusarium moniliforme* and *Curvularia* sp. were isolated from different test rice varieties.Ora *et al.* (2011) recorded the seed borne pathogens *viz*. *Fusarium moniliforme, Aspergillus* sp.,*Bipolaris oryzae, Xanthomonas oryzae, Curvularia lunata, Rhizopus stolonifer, Phoma* sp*., Penicillium* sp.,*Tilletia barclyana, Chaetomium globosum,Alternaria tenuissim a*and *Nigrospora oryzae* associated with cultivated hybrid rice genotypes (two local hybrids, thirteen imported and two local rice varieties as check). Among these pathogens

Bipolaris oryzae, Fusarium moniliforme, Xanthomonas spp*., Rhizopus stolonifer* and *Aspergillus* sp., were predominant on all tested hybrid rice varieties. For the identification process blotter method, agar plate method and paper towel method were used.

Utobo *et al.* (2011) isolated and identified nine fungal genera colonized with eight hybrids and three local check rice varieties seed samples procured from four rice fields located at the place of Nigeria and fungi like *Trichoconis padwickii* (38.14% H; 37.41% LC), *Helminthosporium oryzae* (18.14% H; 17.85% LC), *Fusarium moniliforme* (15.29% H; 15.13% LC) for hybrids and local check rice varieties respectively. Percentage of germination and seedling vigour were found significant from hybrid to local check rice varieties.

Uma and Wesely (2013) identified the fungi associated with seeds of five cultivars of rice by Agar and Blotter paper methods. The pathogenic fungi *Alternaria padwickii, Aspergilus niger, Aspergillus flavus,* and *Rhizopus oryzae* were isolated and identified from seeds of different rice genotypes.

Rawtec (2013) reported the discoloured seed colonized with several pathogenic and saprophytic fungi *viz.*, *Sarocladium* sp., *Curvularia* sp., *Alternaria* sp., *Pyricularia* sp., *Fusarium* sp., *Penicillium* sp., *Phyllosticta* sp., *Diplodia* sp., and *Aspergillus* sp. and the detection of mycoflora was done by standard blotter paper method.

Sabina *et al*. (2018) isolated five fungal genera of *Alternaria* sp*., Aspergillus* sp*., Curvularia* sp*., Bipolaris* sp. and *Rhizopus*sp. from discoloured glumes, endosperm and embryo of discoloured grains of rice by component plating method. Among the fungi isolated from glumes, *Aspergillus* sp. (37.83 %) was predominant and followed by *Alternaria* sp. (20.83 %), *Curvularia* sp. (17.83 %), *Bipolaris* sp. (17.17 %) and *Rhizopus* sp. (6.33 %). Similarly, *Aspergillus* sp. (48.33 %) was the most predominant followed by *Bipolaris* sp. (17.33 %), *Alternaria* sp. (15.50 %), *Curvularia* sp. (14.33 %) and *Rhizopus* sp. (4.50 %) in embryo. Similarly, in endosperm, *Aspergillus* sp*.,* (50.50%) was dominant and followed by *Bipolaris* sp. (22.17%), *Curvularia* sp. (17.17%), *Alternaria* sp. (8.83%) and *Rhizopus* sp. (1.33%).

Table 2.1 List of externally seed borne fungi associated with grain discolouration

Pathogens	References
Alternaria spp.	Reddy and Khare (1979); Zakeri and Zad (1987); Sachan andAgarwal (1995); Saifulla*et al*. (1996a); Pandey *et al*. (2000);Bag *et al.*, (2010); Gopalakrishnan *et al.* (2010a); Ora *et al*. (2011);Gautam *et al*. (2012); Islam and Borthakur (2012); Ahmed *et al.* (2013); Bhuiyan *et al*. (2013); Rawtec (2013); Uma and Wesely (2013); Aurangzeb *et al*. (2014); Ibrahim and El-Dahab (2014); Zafar *et al*. (2014); Sabina *et al*. (2018)
Aspergillus spp.	Saifulla*et al*. (1996a); Bag *et al.*, (2010); Ora *et al*. (2011);Gautam *et al*. (2012); Islam and Borthakur *(*2012); Ahmed *et al.* (2013); Bhuiyan *et al*. (2013); Rawtec (2013); Uma and Wesely (2013); Zafar *et al*. (2014); Sabina *et al*. (2018)
*Cercospora*spp.	Arunyanart*et al*. (1981)
Chaetomium spp.	Saifulla*et al*. (1996a); Gopalakrishnan *et al.* (2010a); Ora *et al*. (2011); Islam and Borthakur (2012)
Cladosporium spp.	Saifulla*et al*. (1996a); Gautam *et al*. (2012)
*Curvularia*spp.	Supriaman and Palmer (1980); Zakeri and Zad (1987); Rodriguez*et al*. (1988); Jin (1989); Sachan and Agarwal (1995); Saifulla *et al*.(1996a); Pandey *et al*. (2000); Akila and Ebenezer (2009); Bag *et al*.(2010); Gopalakrishnan *et al.* (2010a); Ora *et al*. (2011); Gautam*et al*. (2012); Islam and Borthakur (2012); Ahmed *et al.* (2013);Bhuiyan *et al*. (2013); Rawtec (2013); Aurangzeb *et al*. (2014);Ibrahim and El-Dahab (2014); Sachanand Agarwal (1995); Zafar *et al*. (2014); Sabina *et al*. (2018)
*Diplodia*spp.	Rawtec (2013)
Fusarium spp.	Supriaman and Palmer (1980); Rodriguez *et al*. (1988); Saifulla*et al*. (1996a); Pandey *et al*. (2000); Haque *et al*. (2007); Akila and Ebenezer (2009); Bag (2010); Gopalakrishnan *et al.* (2010a); Ora*et al*. (2011); Gautam *et al*. (2012); Islam and Borthakur (2012); Ahmed *et al.* (2013); Bhuiyan *et al*. (2013); Rawtec (2013); Aurangzeb *et al*. (2014)
*Microdochium*spp.	Saifulla*et al*. (1996)
*Nigrospora*spp.	Saifulla*et al*. (1996a); Pandey *et al*. (2000); Ora *et al*. (2011); Ahmed *et al.* (2013); Rawtec (2013); Aurangzeb *et al*. (2014)
Penicillium spp.	Ora *et al*. (2011); Gautam *et al*. (2012); Islam and Borthakur (2012); Ahmed *et al.* (2013); Rawtec (2013); Uma and Wesely (2013); Zafar *et al*. (2014)
*Phoma*spp.	Saifulla*et al*. (1996a); Ora *et al*. (2011); Aurangzeb *et al*. (2014)
*Pyricularia*spp.	Zakeri and Zad (1987); Sachan and Agarwal (1995); Saifulla*et al*.(1996a); Pandey *et al*. (2000); Haque *et al*. (2007); Aurangzeb *et al*. (2014); Ibrahim and El-Dahab (2014); Zafar *et al*. (2014)
Rhizoctonia spp.	Haque *et al*. (2007)
Rhizopus spp.	Rawtec (2013); Uma and Wesely (2013); Zafar *et al*. (2014);
	Sabina *et al*. (2018)
*Sarocladium*spp.	Pandey *et al*. (2000); Haque *et al*. (2007); Bag *et al.* (2010); Gopalakrishnan *et al.* (2010b); Islam and Borthakur (2012); Bhuiyan *et al*. (2013); Rawtec (2013)
Sclerotium spp.	Haque *et al*. (2007)
Trichoderma spp.	Gopalakrishnan *et al.* (2010a); Rawtec (2013)
Verticillium spp.	Saifulla*et al*. (1996)

Table 2.2 List of internally seed borne fungi associated with grain discolouration

Pathogens	References
Alternaria spp.	Padmanabhan (1949); Reddy and Khare (1979); Khan *et al.* (1988); Bhat *et al.* (2009a); Butt *et al.* (2011); Islam andBorthakur (2012); Uma and Wesely (2013); Ahmad *et al.* (2013); Sabina *et al*. (2018)
Aspergillus spp.	Khan *et al.* (1988); Kheroda and Chhetry (2008); Bhat *et al.*(2009b); Islam and Borthakur (2012); Uma and Wesely (2013); Ahmad *et al.* (2013); Sabina *et al*. (2018)
Chaetomium spp.	Khan *et al.* (1988); Ibiam*et al*. (2008)
Cladosporium spp.	Islam and Borthakur (2012)
*Curvularia*spp.	Khan *et al.* (1988); Sachan and Agarwal (1995); Pandey *et al*. (2000); Kheroda and Chhetry (2008); Bhat *et al.* (2009a); Butt *et al.* (2011); Ahmad *et al.* (2013); Ibrahim and El-Dahab (2014); Sabina*et al*. (2018)
Fusarium spp.	Kheroda and Chhetry (2008); Bhat *et al.* (2009a); Butt *et al.* (2011); Ahmad *et al.* (2013)
Helminthosporium spp.	Zakeri and Zad (1987); Khan *et al.* (1988); Pandey *et al*. (2000); Ibiam*et al*. (2008); Kheroda and Chhetry (2008);Bhat *et al.* (2009a); Butt *et al.* (2011); Islam and Borthakur (2012);Ahmad *et al.* (2013); Sabina *et al*. (2018)
Myrothecium spp.	Khan *et al.* (1988)
*Nigrospora*spp.	Zakeri and Zad (1987); Sachan and Agarwal (1995); Pandey*et al*. (2000); Kheroda and Chhetry (2008); Ibrahim and El-Dahab (2014)
Penicillium spp.	Islam and Borthakur (2012); Uma and Wesely (2013)
*Pyricularia*spp.	Zakeri and Zad (1987); Sachan and Agarwal (1995); Pandey *et al*. (2000); Bhat *et al.* (2009a); Ibrahim and El-Dahab (2014)
Rhizoctonia spp.	Bhat *et al.* (2009a)
Rhizopus spp.	Islam and Borthakur (2012); Uma and Wesely (2013); Ahmad*et al.* (2013); Sabina *et al*. (2018)
*Sarocladium*spp.	Zakeri and Zad (1987); Sachan and Agarwal (1995); Pandey*et al*. (2000); Ibrahim and El-Dahab (2014)
*Trichoconis*spp.	Khan *et al.* (1988)
Trichoderma spp.	Ibiam *et al*. (2008)
*Trichotheciu*mspp.	Bhat *et al.* (2009a)

2.3 Screening of genotypes for reaction to grain discolouration of rice

Rao and Poornachandrudu (1971) reported that the sorghum varieties IS 452, IS 456, IS 472 and IS 473 have been found fairly resistant to grain molds.

Kulkarni *et al.* (1975) reported that during *Kharif*, sorghum grain discolouration was observed in all the varieties and hybrids except CS 3541, 2219A x CS 3542, 2077 and CS 3541 A. Further, they concluded that 65 single plant selections from F_4 generation of H-112 x CS 3541 have been found resistant to grain molds.

Among 15 genotypes of sorghum screened for mold resistance, IS 472, IS 451 and 2219 B were least susceptible while IS 3722, CSH-5, IS 455, CS 3541, Khedi-22-10 and 472 (R) were moderately susceptible and remaining were highly susceptible (Rao and Rao 1975). Murthy *et al.* (1977) obtained one homozygous line resistant to molds from F_6 generation of the cross CS 3541 x H-112. They bulked seeds from that line and named it as H-113 and confirmed its resistance to grain molds both in field and in laboratory. Rao and Williams (1977) reported from field screening programme of 6000 sorghum lines in 1975 and 1976 only 43 lines are relatively less susceptible.

Denis and Girard (1978) concluded that the variety IS 2327 was found to be resistant to grain molds. A few other varieties showed slightly tolerance to grain molds.

Parmeshwarappa *et al.* (1978) reported IS 2328, IS 8717, IS 8312, IS 2245, IS 5821, IS 9408, IS 1394-1, IS 8305, IS 9796, IS 30098, IS 4950-1, IS 7248, IS 4222, IS 4460 and IS 9121 as grain mould resistant lines.

Reddy *et al.* (1978) reported that released hybrids like CSH-5 and its male parent CS 3541, CSH-6 and pre-released sorghum project varieties and hybrids at Agricultural Research Institute, Hyderabad, have exhibited resistance to grain molds. They further mentioned that in addition to some of the IS lines and Ethiopian lines, E 35-1 has also exhibited resistance to grain molds.

Reddy and Reddy (1978) screened sorghum lines resistance to *Fusarium*, *Curvularia* and *Alternaria* and found SPH-51, SPH-80, CSV-7R, SPV-50, SPV-99, SPV-

138, SPV-142, SPV-202 and 36 B free from grain molds and others showing moderate to traces of infection.

Gangadharan *et al.* (1979) screened 32 sorghum entries for their reaction to *Curvularia lunata* and *Fusarium moniliforme* on the basis of scale (1-5). According to them, CSV-4, CSH-5, CSH-6, CSH-7R, Co-21, Co-22, Co-23, COH-2 and USH-1 were moderately resistant, and K-3 was resistant to head molds.

Rao *et al.* (1979) reported that out of the 857 entries screened, 157 were rated as low susceptible with rating of 2 on a disease rating scale of (1-5). Seven entries *viz.,* IS 1433, IS 2327, E 35-1, 9225, IS 2261 and IS 2435 were less susceptible to *Fusarium, Curvularia* and *Phoma* under natural infection conditions. Out of 28 entries screened for *Fusarium* and *Curvularia*, 12 entries were rated as 2 and 9 of them were also less susceptible to *Phoma* incidence.

Bernhardt *et al.* (1997) reported that between 1988 and 1994, only one rice cultivar Mercury has exhibited discolouration that were much higher than the others. In 1995, Louisiana released a new cultivar called Lafitte. The parents of Lafitte were Mercury and Koshihikari. In evaluations of the 1995 URRN samples, Lafitte was found to have very high amounts of discolouration. Results of the 1996 ARPT evaluations for discolouration showed that Koshihikari, M202 and Lafitte are much more susceptible to conditions that cause the discolouration. It is suspected that high temperatures during grain filling or maturation cause more discolouration in susceptible types.

Divya (2015) reported that grain discolouration was the highest in NLR 34449 (40.68%) which was significantly higher than in other variety. The lowest grain discolouration was recorded in MTU 1010 (14.78%) which was on a par with BPT 1768, MTU 1064 (15.93%) and NLR 3041 (19.05%).

2.4 Effect of grain discolouration on biochemical constituents of rice

2.4.1 Total Phenols

The rice grains infected with *C. lunata* and *H. oryzae* showed higher level of phenol content (Duraiswamy and Mariappan, 1983). The phenol content was raised

observed in infected rice grain through a PPO-PO-H_2O_2 system when the phenol compound gets oxidized later leads to resistance (Srivastava, 1987). The quantum of phenol content was increased and it varied from 7.67 % to 70.78 % when rice grains infected with *S.oryzae* and phenol content significantly increased in all age group of rice plants when inoculated with *Sarocladium oryzae* due to activation of defense mechanism at the site of infection. (Raja and Syamala, 2012, Gopalakrishnan *et al*., 2010 and Velazhahan and Ramabadran, 1993). The increased enzymatic activity of polyphenol oxidase and peroxidase leads to increased the phenol content in rice discoloured grains (Khatun *et al*., 2009). Total phenols content was significantly higher in all tested genotypes in discoloured grains than in healthy grains. (Divya, 2015)

2.4.2 Total Sugars, reducing sugars and non reducing sugars

The increase in total sugar content was more in diseased grains than healthy grain in all rice genotypes which was observed mainly because of the requirement of more sugars by the infected pathogens for pathogenesis and further development within the host tissue (Duraiswamy and Mariappan, 1983 and Saifulla*et al.*1998).

They observed the increased reducing sugar and non reducing sugar level when the infection increased in the rice grains and content varied with one genotype to another genotype (Duraiswamy and Mariappan, 1983 and Saifulla*et al.*1998).

2.5 Management of grain discolouration in rice through fungicides and Bio-fungicides

Dharm Vir (1970) reported that dithane M-45 was found effective against *Drechslera* spp. as seed treating fungicide as compare to other fungicides. Singh and Chand (1985) reported that among fungicides tested iprodione 0.75 kg ha^{-1} + edifenphos 1 l ha^{-1} or iprodione 0.75 kg ha^{-1} + zineb 2 kg ha^{-1} or edifenphos 1l ha^{-1} also reduced grain discolouration when sprayed at 10% panicle emergence.

Mishra and Tewari (1992) tested the ethanolic extract and found to have more effective and broad-spectrum fungal toxicity against four pathogens of rice *viz*., *Rhizoconia solani, P. oryzae, A. niger* and *C. lunata*. Different workers reported

Carbendazim as the most effective fungicide against grain discolouration (Ray, 1993). Chowdhury(1995) reported that the oil extracted from the leaves of *Chenopodium abrosioides* at a concentration of 2000 ppm and oil extracted from seeds of *Ocium canum*, *Anethum graveolens* and *Pimpinella anisum* at concentration of 3000 ppm exhibited complete mycelium inhibition of all test pathogens viz., *Colletotrichum falcatum, Fusarium moniliforme, Rhizoctonia solani, Ceratocystis paradoxa Curvalaria lunata,Periconia atropurpurea* and *Epicoccum nigrum*. *Pimpinella anisum* was fungicidal at 3000 ppm to *C. falcatum, R. solani* and *C. paradoxa*.

Rajappan *et al.* (200l) reported that neem and pungam, a oil-based emulsifiable concentrate (EC) formulations developed at Tamil Nadu Agricultural University were evaluated for their efficacy to inhibit the mycelial growth of the fungi *H.oryzae* and *P. oryzae* causing grain discolouration on rice under *in vitro* conditions. All three formulations, *viz.,* neem oil 60 EC (acetic acid), neem oil 60 EC (citric acid) and neem oil + pungam oil 60 EC (citric acid) inhibited mycelia growth of the pathogens. They were effective even after 9 months of storage. These formulations effectively controlled the grain discolouration on rice.

Krishnappa *et al.* (2005) reported that the extracts of *Polyalthia longifolia* controlled *C. lunata (*59 %*), Drechslera oryzae* (50 %) and *T. padwickii* (59-63%). The leaf extract of *Datura stramonium* L. inhibited *T. padwickii, D. oryzae* and *C. lunata* (34-74%). The aqueous extracts of *Allium cepa* (50%) controlled *Curvularia lunata, D. oryzae* and*Trichoconiella padwickii* (35-62%).

Bacillus subtilis BR23 used for seed treatment and had no detrimental effects on corn seed germination and seedling vigour. Seed treatment with same formulation suppressed *R. solani* in microplots and increased grain yield by 27 per cent compared to that of the captan seed treatment showed (14.4 per cent). *B. subtilis* BR23 has a potential for commercialization as a seed treatment for the control of banded leaf and sheath blight disease (*R. solani*) in corn (Amran Muis and Arcadio, 2006).

Three fungicides *viz.*, propiconazole, carbendazim and hexaconazole were tested against grain discolouration disease of rice. Among them, the propiconozole was found more effective in reduction of disease (6.12%) followed by carbendazim (12.90%) and hexaconazole (14.10%) (Lore *et al*., 2007).

Sumangala *et al.* (2008) studied *in vitro* evaluation of four systemic fungicides. Among them, difenaconazole (98.80%) and propiconazole (98.10%) at 0.1 per cent concentration has showed maximum inhibition of mycelia growth of *Curvularia lunata*. Among the three non-systemic fungicides tested, mancozeb (98.80%) was found most effective followed by chlorothalonil (63.67%) at 0.2 per cent concentration. Among bio control agents, *B. subtilis* (97.77%), *Trichoderma viride* (96.44%) and *Trichoderma. harzianum* (93.50%) were found effective in inhibiting the radial growth of fungus.

Imran Arshad *et al.* (2009) have tested four fungicides were tested for the management of grain discolouration in rice *viz.,* Dithane M-45, topsin-M, carbendazim and ridomil. Dithane M-45 and ridomil showed best control of mycelial growth of all isolated pathogens except *Fusarium moniliforme,* where carbendazim was found to be the best and which was followed by topsin-M, dithane M-45and ridomil, respectively.

Fungicides significantly reduced the disease and increased the grain yield over untreated check plot. Among these, carbendazim performed better in reducing panicle infection (59.3%) and spikelet infection (11.6%) and was followed by carbendazim + mancozeb which reduced both the panicle and spikelet infection by 59.5 and 12.3 per cent, respectively. But carbendazim and carbendazim + mancozeb were at par in reducing the disease and protecting the grain yield of rice (Manas Kumar *et al*., 2010).Other fungicides reported to be effective against grain discolouration were di-isopropyl benzyl thiophosphate (Ray, 1993), carbendazim + mancozeb (Anwar and Bhat, 2008), mancozeb, hexaconazole (Bag and Biswas, 2010), rovral (iprodione) and Folicur (tebuconazole) (Akter *et al*., 2013).

III MATERIAL AND METHODS

The present investigation on grain discolouration of rice was carried out during *Kharif* 2017 and 2018 at the Department of Plant Pathology, College of Agriculture, GKVK, Bengaluru and ICAR-Krishi Vigyan Kendra, Chamarajanagara.The details of material used, and methodologies followed are described here under.

3.1 MATERIALS

3.1.1 Glassware

The glasswares used in the present study were of Corning or Borosil make. The Petri plates, test tubes, pipettes, measuring cylinders, beakers, conical flasks, micropipettes and microtips were used in the present study.

3.1.2 Cleaning of Glassware

Glasswares washed first with detergent powder and then cleaned under running tap water. Later they were placed overnight in cleaning solution containing potassium dichromate (75 gm), concentrated sulphuric acid (500 ml) and distilled water (1000 ml) and later cleaned with running tap water followed by distilled water.

3.1.3 Chemicals

Analytical or reagent grade chemicals were used in the present study.

3.1.4 Instrument

As per the requirements, the following instruments were used to carry out the present studies.

1. Sterilization purpose autoclave was used
2. Incubation ofpathogen done in BOD incubator
3. Identification ofpathogens done in Compound and Stereo microscope
4. Glasswaresterilization in Hot air oven
5. Isolation, purification and inoculation ofpathogen was done in Laminar air flow

6. Weighing of chemicals done in Electronic digital balance
7. Needles, forceps, blades, spirit lamp, scalpel, knives and spatule
8. Melting ofmedia done in Micro oven
9. Growth chamber
10. Rotary shaker foragitation
11. Studied the habit of thecolonies using byStereo binocular microscope
12. Centrifuge
13. Hand lens

3.2 METHODS

3.2.1 Culture Media

The culture media used in the present study was prepared by following the methods given by Dhingra and Sinclair (2000).The fungal cultures *viz.*, *Curvularia* sp., *Alternaria* sp. and *Helminthosporium* sp. were isolated, purified, maintained and multiplied on potato dextrose agar (PDA) medium.

Composition of PDA	Quantity (gm)
Pototo pieces (Peeled)	200
Dextrose	20
Agar agar	20
Distilled water	1000 ml

Weighed 200 gm of potato, peeled off and made in to slices, later these were boiled in 500 ml of distilled water until the potato slices became soften and kept for cooling, after using by muslin cloth the extract was filtered and added 20 gm of Dextrose. Melted 20 g of agar agar in 500 ml of distilled water and was added to the prepared potato dextrose broth. Made up the volume to1000 ml by adding distilled water. Adjusted pH of the medium to 6.5 using either 0.1 N sodium hydroxides (NaOH) or 0.1 N hydrochloric acid before sterilizing in autoclave.

3.2.2 Preparation of slants

Molten PDA was poured in culture tubes, by using non-absorbent cotton it was plugged and was sterilized. Later, they were placed in slanting position for solidification and further these were transferred to the refrigerator for maintenance.

3.2.3 Sterilization

Sterilized glassware in hot air oven at 180 °C for an hour and in autoclave, the culture media were sterilized at 121.6 °C at 15 psi pressure for 15 minutes. Loops, cork bores and inoculation needles were sterilized by using flame. Surface sterilization of healthy and diseased seeds were done by dipping in 1% sodium hypochlorite (NaOCl) for one minute and further washed serially with sterilized water thrice and later seeds were dried.

3.3 Collection of seed samples

Seed samples were collected through roving surveyconducted during*Kharif* 2017 and *Kharif* 2018 from farmer's fields of Mysore, Mandya, Chamarajanagara, Kodagu, Uttar Kannada, Yadagir, Raichur, Koppal, Ballari, Shivamogga, Chikkamagaluru, Davanagere and Dakshina Kannada districts representing five rice growing ecosystem. In each district, one or two taluks were selected. In each taluk, three villages were selected and in each village, three plots were surveyed and were listed in the Table 3.1. Randomly 10 representative panicles from different fields at each location from different of cultivars were collected, labeled and packedin paper bags and were stored at room temperature (30 ± 2 °C) for further investigation. Later separated grains from selected ten representative panicles from each location and bulked separately. Of which four hundred grams of samples was drawn from each bulk sample and used for estimating incidence and severity of grain discolouration by using 0-9 standard evaluation system scale given by IRRI, 2013 and described in (Plate 1).

Per cent disease index was worked out by using the formula given by Wheeler (1969)

$$\text{PDI} = \frac{\text{Sum of individual diseased grain ratings}}{\text{Number of grains assessed}} \times \frac{100}{\text{Maximum grade}}$$

Table 3.1 Details of roving survey conducted during *Kharif* 2017 and 2018 to study the severity of grain discolouration

Ecosystem	District	Taluk	Village	No of field
Hilly upland	Kodagu	Ponnampet	Hudikeri	3
			Srimangala	3
			Balele	3
	Uttara Kannada	Sirsi	Yedurbail	3
			Bashi	3
			Gudnapur	3
Coastal belts	Uttar Kannada	Uttar Kannada	Mundugodu	3
			Kumata	3
			Honnavar	3
	Dakshina Kannada	Udupi	Barkur	3
			Kundapur	3
			Udupi	3
		Mangaluru	Mudbidari	3
			Beltangdi	3
			Mangaluru	3
Irrigated Kabini and Kaveri	Chamarajanagara	Yalandur	Y.K.Mole	3
			Yariyuru	3
			Maddur	3
		Kollegal	Madhuvanahalli	3
			Gowdalli	3
			Uttamballi	3
	Mandya	Mandya	Mandya	3
			Holalu	3
			Mallanayankanakatte	3
		Maddur	Devarahalli	3
			Doddaarasinakere	3
			Alemanegate	3
		Pandavapura	Pandavapur	3
			Agatahalli	3
			Alphahalli	3
	Mysuru	Mysuru	Suttur	3
			Basavanapur	3
			Horalawadi	3
Irrigated	Shivamogga	Shivamogga	Gondhichatttanahalli	3

Ecosystem	District	Taluk	Village	No of field
ecosystem ofThunga and Bhadra			Harakere	3
			Holaluru	3
	Chikkamagaluru	Tarikere	H. Rangapur	3
			Halasur	3
			Hanne	3
	Davanagere	Channagiri	Kariganur	3
			Kasipur	3
			Arehalli	3
		Harihara	Nandigavi	3
			Gondajji	3
			Rajanahalli	3
		Davanagere	Maragondanahlli	3
			Kadlebalu	3
			Avaragolla	3
	Ballari	Harapanahalli	Hiremegalegere	3
			Nitur	3
			Alavagulu	3
Irrigated ecosystems of TBP and UKP command	Raichur	Sindhanoor	Gorebal	3
			Sindhanoor	3
			Javalagera	3
	Koppal	Gangavathi	Basavapattana	3
			Heruru	3
			Anegundi	3
	Ballari	Siruguppa	Siruguppa	3
			B.M.Sugur	3
			Balakundi	3
		Hosapet	Amalapur	3
			Kampli	3
			Ramasagara	3
		Ballari	Emmignur	3
			Guttiganur	3
			Kottal	3
	Yadgiri	Shahpur	Hothpete	3
			Shahapur	3
			Gogi	3

Per cent grain discolouration was calculated by using the formula

$$= \frac{\text{Number ofpanicles affected}}{\text{Total number of panicles observed}} \times 100$$

3.4 Seed germination test

Twenty fivediscoloured seeds were drawn from each grade *viz.*, 0%, <1%, 1 -5%, 6-25%, 26-50% and 51-100% and healthy sample from each sample. Four replications were maintained and assessed per cent germination by following paper towel method described by International Rules for Seed Testing. These twenty-five seeds were incubated in moistened germination paper. The percentage of germination was calculated after seven days of incubation by using the formula.

$$\text{Germination percentage} = \frac{\text{No. of seeds germinated}}{\text{Total No. of seeds}} \times 100$$

3.5 Isolation of seed borne fungi from discoloured grains

3.5.1 Characterization of fungal pathogens associated with rice grain discolouration

For visual examination of discoloured seeds, the seed samples wereexamined with naked eye. Each seed sample was mixed thoroughly, and a working sample of 400 g was collected for the study of grain discolouration. The apparently healthy, discoloured and chaffy seeds were separated on visual appearance basis. The discoloured seed lot comprised different symptoms *i.e.*, light pink, light brown, brown, dark brown, blackdiscolouration and necrotic spot of the seed. The per cent discolouration was calculated following the general arithmeticrule.

$$\text{\% Discoloured grains (number based)} = \frac{\text{No. of discoloured grains}}{\text{Total No. of grains}} \times 100$$

Scale	Description	Images
0	No symptom of discolouration	
1	Less than 1% discolouration	
3	1 to 5 % discolouration	
5	6 to 25 % discolouration	
7	26 to 50 % discolouration	
9	51 % to 100% discolouration	

Plate 1: Standard evaluation system scale (0-9) used for measuring disease Incidence and disease severity of grain discolouration in rice

3.6.1 Isolation and characterization of associated seedmycoflora

Characterization of seed mycoflora associated with grain discolouration of rice was carried out based ontheir cultural and morphological characteristics such as colony colour, colony character, spore shape, spore size and type of spore formation (Malone and Muskette, 1964; Neergaard and Saad, 1962).

3.6.2 Cultural studies of differentmycoflora

The cultural characters of various pathogens associated with discoloured seeds were studied on potato dextrose agar media. In each petriplate, poured 20 ml of PDA medium and kept for solidification. By using of cork borer, cut in to 2 mm disc of pathogen from the actively growing tips and one disc was placed upside down at the centre of the Petridish.

These plates were incubated at 28±2°C. Three replications were maintained for each set of the experiment. When attained maximum growth of mycelia, the colony diameter was measured and other cultural characters like colony colour and volume of mycelia mass were also recorded.

3.6.3 Morphological studies of different mycoflora

For morphological studies ofconidia, hyphae and conidiophores, temporary slides were prepared in lacto-phenol stained with cotton blue. Prepared slides were examined under the compound microscope and measured length and width of conidia, conidiophores length and number of septa in each conidium.

3.6.4 Assessment of mycoflora associated with discoloured grains

Assessment of associated pathogens with discoloured grains was studied by using following standard methods

Examination of seeds with incubation (ISTA, 1996)

i. Standard blotter method
ii. Agar plate method
iii. Paper towel method

3.6.5 Standard blotter method

This method was more useful to detect the presence of pathogens on or in the seeds and also suitable for detection of fast-growing organisms than the slow growing ones. In each Petri dishes of nine cm in diameter, same diameter of two blotter paper were kept and moistened with sterile distilled water.

Twenty-five seeds were placed on the blotters in each Petri plate. These 25 seeds were arranged in such a manner that in outer circle placed 16 seeds and in inner circle placed 8 seeds and 1 seed was kept in the centre of the plate. For each genotype, four replicated plates were maintained. Total 100 seeds were used for four replications in each genotype. Later, these replicated plates were incubated in light and dark condition alternatively for 12 hours. The seeds were examined under stereo-binocular microscope after seven days of incubation and recorded the per cent incidence of various seed borne pathogens.

3.6.6 Agar plate method

Potato dextrose agar medium (15-20 ml) was poured into sterilized Petri plates in laminar air flow chamber. At the time of pouring media, 0.1 gm streptomycin sulphate per flask was added to avoid bacterial contamination. Twenty-five discoloured seeds of each genotype were selected and surface sterilized with 0.1% NaOCl for thirty seconds and washed twice with sterile distilled water. Further, these seeds were placed in Petri plates contained in equidistance PDA media. Totally 4 plates were maintained for each genotype and these plates were kept for incubation at 24±2ºC under light and dark conditions alternatively. Later, fungal colonies of each plate were observed from 6^{th} to 8^{th} day for each tested genotype. The colony characters were observed under stero-binocular microscope and mycelia, hyphae and spores were observed under compound microscope.

3.6.7 Paper towel method

In seed testing laboratories, this method is generally used for measuring seed germination. The same method was also used for detection of seed borne fungi that caused decaying of seed, seedling blight and mortality of seedlings. Two sheets of square

blotter paper towels with size of 23x 26.5 cm and were moistened in distilled water later 100 seeds were placed in 10 rows of 10 seeds on one of the wet paper towels. Then cover the seeds used by another wet paper and rolled and closed the ends of paper towel by using rubber bands. To maintain the humidity these rolled paper towels were covered with a transparent plastic sheet. For each genotype, 200 seeds were tested in two replications. Further, these paper towels were placed in an upright position in a plastic tray. The setup was incubated for 5 to 9 days at 28-30 °C under 12 hours of light. The rubber bands were removed after 5 to 9 days of incubation and examined the seeds for growth of mycoflora and development of symptoms on seedlings.The symptoms developed on seedlings were recorded in each each genotype and isolated the colonized pathogens from the diseased parts of the coleoptiles / seedling by placing on potato dextrose agar plates under aseptic conditions.

3.7 Purification of isolated fungal cultures

Single spore isolation method was used for obtaining pure cultures of all isolates. Prepared spore suspension by scraping the surface of sporulating cultures and was added to lukewarm molten water agar and dispensed into sterilized Petri plates. The Petri plates were gently swirled both clockwise and anti-clockwisefor even distribution of spores and kept for incubation at 25 ±2 °C for 12 h. Individual germinated spore spaced out clearly was located on inverted water agar plates and marked with a glass marking pencil on outside bottom of the dish. Each marked spore was aseptically transferred into separate PDA slants. The culture was maintained and sub-cultured for further studies.

3.8 Preservation of fungal cultures

All the isolates of sub-cultured pathogens were preserved in a refrigerator at 4°C by using sterilized mineral oil and restored to active state by sub-culturing on to a fresh potato dextrose agar medium.

3.9 Screening of rice genotypes for grain discolouration disease

Thirty-eight rice genotypes were obtained from Division of Rice Breeding, AICRP (Rice), Zonal Agricultural Research Station, V.C.Farm, Mandya for screening

against grain discolouration. The experiments were conducted in the farmer's field of Yalandur taluk, Chamarajanagara district during *kharif* 2017 and 2018. The experiment was laid out in Randomized Black Design (RBD) with two replications with a plot size of 3 m^2 and spacing of 20 x 10 cm. The crop was raised following general package of practices of University of Agricultural Sciences, Bangalore with N: P: K of 100:50:50 per hectare. At maturity, five panicles from each entry were collected and threshed grains were assessed for percent discolouration by counting the number of healthy and discoloured grains in each sample. The per cent discolouration was calculated by using the following formula:

$$\% \text{ Discolored grains (number based)} = \frac{\text{Number of discolouredgrains}}{\text{Total number of grains}} \times 100$$

Later, based on 0 to 9 disease rating scale, the rice genotypes were grouped in to immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible (IRRI,2013).

Table 3.2 Standard evaluation disease scale (0-9) used for assessment of incidence and severity of grain discolouration (IRRI, 2013)

Disease Score (0 –9)	Description	Response
0	No symptom of discolouration	Immune
1	Less than 1% discolouration	Resistant
3	1 to 5 % discolouration	Moderately Resistant
5	6 to 25 % discolouration	Moderately Susceptible
7	26 to 50 % discolouration	Susceptible
9	51 % to 100% discolouration	Highly Susceptible

Table 3.3 List of rice genotypes screened for grain discolouration

Sl. No.	Genotypes	Sl. No.	Genotypes	Sl. No.	Genotypes
1.	Rasi	14.	Basumati-270	27.	Jaya
2.	KMP-153	15.	IR-30864	28.	Gangavathi Sona
3.	IR-64	16.	Jyothi X BR-2655	29.	Mandya Vijaya
4.	Mandya Sona-2	17.	CTH-1	30.	KCP-1
5.	Raksha	18.	HR-12	31.	MTU-1001
6.	KMP-201	19.	MSN100	32.	Tellahamsa
7.	KMP-128	20.	KMP-200	33.	Rajamudi
8.	KMP-175	21.	CTH-3	34.	Thanu
9.	BR-2655	22.	GVT-7	35.	Ratnachudi
10.	Jaya X ASD-16	23.	GVT-4	36.	RNR-15048
11.	MTU -1010	24.	JGL-1798	37.	MSN-99
12.	BPT-5204	25.	KRH-4	38.	KMP-149
13.	Jyothi	26.	MandyaSona-1	-	

Table 3.4 Weather parameters recorded during *Kharif* 2017 and *Kharif* 2018 at RSRS, Chamarajanagara

Months	Rainfall (mm)		Temperature (°C)		Temperature (°C)		R.H (%)		R.H (%)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
	2017	2018	2017	2017	2018	2018	2017	2017	2018	2018
January	0	0	31.1	10.5	32	10	80	16	90	22
February	0	0	36.9	11	34.4	9.4	75	12	83	17
March	50.6	36.2	36.9	11.5	36	12.89	83	15	100	12
April	57.2	59.2	37.3	19.3	36.3	19.2	90	15	84	31
May	188.5	203.4	37	18.4	36.1	20	91	32	92	43
June	6.2	20.8	32.9	19.7	32.5	18	81	45	95	54
July	20.2	21.8	33.4	19.2	32.5	19	91	47	91	47
August	136.4	87.4	33.4	19	31	18.4	100	44	91	55
September	198.8	92.8	32	19.4	31.28	18.77	97	53	76	55
October	106.6	104.8	31.2	16.2	29.97	18.15	100	48	76	63
November	56.6	22	31.2	17.4	29.48	17.02	97	46	75.63	59.83
December	31.4	3.2	31	10.5	29.81	16.81	96	36	74.32	53.61

3.10 Studies on biochemical changes in discoloured rice grains

3.10.1 Preparation of seed samples

Healthy and discoloured grain samples collected from different locations were pooled variety wise and powdered with the help of pestle and mortar separately.

3.10.2 Estimation of total phenols: Total phenols were estimated by following Folin-Ciocalteau Reagent method (Malick and Singh, 1980).

Reagents

1. Folin-Ciocalteau Reagent
2. 20 % Na_2CO_3
3. 80 % ethanol
4. Standard solution:

Stock Solution: 100 mg of Catechol was dissolved in 100 ml water working standard: 10 ml of stock diluted to 100 ml with water

Procedure for estimation

1. 0.5 g of healthy/ diseased grain samples were made in to powder in pestle and mortar and added with 5 ml of 80% ethanol.
2. Homogenate sample and centrifuged at 10,000 rpm for twenty minutes, saved supernatant and residue was re extracted with 2.5 ml of 80 % ethanol, centrifuged and pooled the supernatants.
3. The supernatants were dried
4. Dissolved residue in 5 ml of distilled water.
5. 0.2 to 2 ml aliquots were pippetted out into tubes
6. Each tube was made up volume to 3 ml with water
7. Added to each tube with 0.5 ml of Folin- Ciocalteau reagent
8. After three minutes, added 2 ml of 20% Na_2CO_3 into each tube

9. Thoroughly mixed contents, exactly one minutes toplaced the tubes in boiling water, cooled and measured absorbance at 650 nm against a reagent blank
10. Prepared standard curve using different concentrations of catechol
11. Calculated the amount of total sugars present in the sample from the graph

$$\text{Total phenols } (\mu g) = \frac{\text{Total volume of aliquot x Phenol value from graph}}{\text{Aliquotused}}$$

3.10.4 Estimation of total sugars: The carbohydrates are the important components in storage and structural materials present in plants. They exist as polysaccharides and free sugars. These are first hydrolyzed into simple sugars using by dilute hydrochloric acid. Total sugars were estimated following Anthrone method (Hodge and Hofreiter, 1962).

Reagents

1. Anthrone Reagent: 200 mg of anthrone is dissolved in 100 ml of ice-cold 95 %
2. $H_2SO_4$2.5 N-HCl
3. Standard Glucose:

Stock Solution: Dissolved 100 mg of glucose in 100 ml water

Working standard: Diluted 10 ml of stock to 100 ml with water and added few drops of toluene and stored at 4 °C

Procedure for estimation

1. Weighed 100 mg of the sample (healthy and diseased) into a boiling tube
2. Placed in a boiling water bath for 3 hours with 5 ml of 2.5 N HCl and cooled at room temperature later it was hydrolyzed
3. Neutralized with solid sodium carbonate until the effervescence ceased
4. Made up to 100 ml volume and centrifuged
5. Collected supernatant and 0.5 ml of aliquot was taken for analysis.

6. Prepared standards by taking 0,0.2, 0.4, 0.6, 0.8, and 1 ml of the working standard and 0' served as blank.
7. Adding by distilled water in each test tube made up to volume of 1ml
8. In each test tube added 4 ml of anthrone reagent and heated for 8 min in a boiling water bath.
9. It was cooled rapidly and the intensity of green to dark green colour was measured in spectrophotometer at 630 nm.
10. A standard graph was prepared by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis.
11. Calculated the amount of total sugars present in the sample from the graph.

Amount of total sugars present in 100 mg of the sample calculated by using formula

$$\text{Total sugar} = \frac{\text{mg of glucose}}{\text{Volume of test sample}}$$

3.10.5 Estimation of reducing sugars: Reducing sugars estimation was carried out byDinitrosalicylic acid method (Miller, 1959).

Reagents

1. 40% of Rochelle salt solution (Potassium sodium tartrate)
2. Dinitrosalicylic acid reagent (DNS reagent): 1 g dinitrosalicylic acid, 200 mg crystalline phenol and 50 mg of sodium sulphite were dissolved in 100 ml of 1% NaOH.
3. Standard Glucose Solution:

Stock Solution: 100 mg of glucose was diluted in 100 ml water

Working standard: 10 ml of stock diluted to 100 ml with water

Procedure for estimation

1. Measured 100 mg of healthy and diseased rice grain sample and sugars were extracted with hot ethanol (80%)
2. Collected supernatant and kept it on a water bath at 80 °C for evaporation
3. Added 10 ml of distilled water and pipetted into 0.5 ml of aliquots in separate test tubes
4. Prepared standards by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard and '0' served as blank.
5. In each test tube added distilled water made up to 3 ml volume
6. Added 3 ml of DNS reagent and placed in a boiling water bath for 5 minutes for heating
7. Added 1 ml of 40% Rochelle salt solution and measured intensity of dark red colour at 510 nm.
8. Amount of total sugars present in the sample tube were calculated from the graph.

$$\text{Amount of reducing sugars} = \frac{\text{Sugar value from graph}}{\text{Aliquot of sample used}} \times \frac{\text{Total volume}}{\text{wt. of the sample}} \times 100$$

3.10.6 Estimation of non-reducing sugars:

The amount of non-reducing sugar wascalculated by deducting the reducing sugar content from that of the total soluble sugars.

3.11 Management of the grain discolouration disease under field conditions withfoliar application of different fungicides

Field experiment was conducted during *Kharif* 2017 and*Kharif* 2018 to study the effect of fungicides and bio agent on the management of grain discolouration in rice.

3.11.1 Experimental site

The experiment was conducted in farmer field at Yalandur taluk in Chamarajanagara district. The experimental field consisted of red soil of fine tilth.

3.11.2 Design and Layout

The experiment was laid out in randomized block design (RBD) with three replications. The layout of the experiment is given in Fig.4.30 and Plate 10.

3.11.3 Date of sowing and Transplantation

Date of sowing : 20.08.2018 and 23.08.2018
Date of transplanting : 15.09.2019 and 19.09.2019

3.11.4 Plot size and spacing

Plot size: 3.0 × 3.0 m
Spacing: 20 × 10 cm

3.11.5 Genotype

A susceptible variety JGL-1798 was used in this experiment.

3.11.6 Land Preparation

The land was prepared by thorough puddling and leveling, and soil was brought to a good tilth.

3.11.7 Fertilizer Application

Fertilizers applied at the rate of 100:50:50 kg N, P_2O_5, K_2O /ha. N and P_2O_5 were applied in the form of urea and single super phosphate and potash in the form of muriate of potash.

3.11.8 Treatment Details

The fungicides were sprayed at panicle emergence stage and 15 daysafter panicle emergence.

Treatments	Foliar spray treatment of fungicides / Bio-fungicide with details
T1	Propiconazole 25% EC @ 0.1% at panicle emergence
T2	Propiconazole 25% EC @ 0.1% at15days after panicle emergence
T3	T1 + T2
T4	Tebuconazole 50%+trifloxystrobin 25% 75 WG @ 0.04 % at Panicle emergence
T5	Tebuconazole 50 %+trifloxystrobin 25% 75 WG @ 0.04 % at 15 days after panicle emergence
T6	T4 + T5
T7	Hexaconazole 5% EC + captan 70 % 75 WP @ 0.2% at panicle emergence
T8	Hexaconazole 5%EC + captan 70 % 75 WP@ 0.2% at 15 days after panicle emergence
T9	T7 + T8
T10	Mancozeb 75% WP @ 0.2% at panicle emergence
T11	Mancozeb75% WP @ 0.2% at 15 days after panicle emergence
T12	T10 + T11
T13	*Pseudomonas fluorescens* @ 0.5% at panicle emergence
T14	*Pseudomonas fluorescens* @0.5% at 15 days after panicle emergence
T15	T13 + T14
T16	Control

3.11.9 Incremental benefit cost ratio

Incremental benefit cost ratio was caluculated by using the formula

$$\text{Incremental benefit cost ratio} = \frac{\text{Net return}}{\text{Cost of treatment}}$$

3.11.10 Harvesting

The crop was harvested at physiological maturityin all plots by cutting at the base of plants. The plants sheaves were sun dried and threshed on threshing floor.

3.11.11 Collection of experimental data

Disease severity: Randomly 10 representative panicles of different cultivars from different fields at each location consisting of different cultivars were collected and separated seeds from panicles. Observations on disease severity were taken.

Per cent disease index was calculated by using the following formula given by Wheeler (1969).

$$\text{PDI} = \frac{\text{Sum of individual diseased grain ratings}}{\text{No. of grains assessed}} \times \frac{100}{\text{Maximum grade}}$$

3.11.12 Yield: Grain obtained from each plot was weighed and recorded in kg andexpressed as q ha^{-1}.

IV RESULTS AND DISCUSSION

In India, rice is not only a major food crop but also an important commercially exporting commodity. It accounts an area of 25.85% and production of 21.6% to global rice production. In the recent past, due to its increased area and drastic changes in climatic conditions the crop is subjected to various biotic and abiotic stresses. Among biotic stresses, diseases are major which affects its grain quality as well as reduce yield. In earlier days, it was reported that the blast, brown spot, sheath blight, bacterial blight, tungro and sheath rot were major diseases, but others were minor diseases. Due to changes in climatic scenario, a minor disease 'grain discolouration' has now became a major one. The same trend was noticed in Karnataka. The incidence and severity of grain discolouration disease varies in Karnataka and it depends on location in which the crop is being cultivated and difference in growing ecosystems *viz*., hilly, costal and irrigated belt of various rivers. These ecosystems represent varied parameters *viz*., rainfall, moisture, humidity, temperature, soil type, season, locality, cultivars, management and micro climatic conditions prevailing particularly from booting to maturity. In recent past, Karnataka is also being considered as one of the hot spot for grain discolouration disease. Keeping all these in view, afocused research work was conducted by conducting roving survey in hilly, costal and irrigated ecosystems, isolated associated organisms from the samples collected from different ecosystems, studied the effect on biochemical parameters, screened thirty eight genotypes and evaluated fungicides under natural conditions.

4.1 Survey and surveillance

4.1.1 Prevalence and spread of grain discolouration disease

In Karnataka, rice is a major crop growing in wide range of soil, agro climatic and growing conditions. These conditions influence mcroclimates of crop and ultimately it reflects on development of various insect pests and diseases. Among diseases, rice grain discolouration is also considered as one of the important diseases and its intensity varies according to agro climatic conditions prevailing in the ecosystems. It includes various factors *viz*. lodging, seasons, location, rain, relative humidity and cloudy weather, prevailing particularly from booting to maturity stage of grain. Hence, it is essential to

know the severity of diseases in different ecosystems of Karnataka and evolve management strategies. Hence, made an attempt to know the intensity of grain discolouration in hilly, costal and irrigated ecosystems of Karnataka. Beside that the survey and surveillance studies on grain discolouration helps to identify the hot spots of grain discolouration disease of rice from three major rice growing ecosystems of Karnataka. The roving survey was carried out to assess incidence and severity of grain discolouration during *Kharif* 2017 and 2018 in different taluks of Uttara Kannada, DakshinaKannada,Chikkamagaluru,Kodagu,Chamarajanagara,Mandya,Mysuru,Davanagere,Shivamogga,Raichur, Koppal, Ballari andYadagir districts representing major three rice growing ecosystems *viz.*, hilly upland, coastal belts, irrigated areas of Kabini, Kaveri, Tunga, Bhadra, Tungabhadra and Upper Krishna in Karnataka. The details of farmer's field surveyed weredepicted in Table 4.1 to 4.3and the grains were graded asdiscoloured or healthy grains for further examination.

During *Kharif* 2017, it has been recorded that the grain discolouration disease was prevalent in all the three rice growing regions with varied incidence and severity. The mean percent disease incidence and intensity ranged from 11.23 to 14.95 and 10.22 to 13.64 respectively (Table 4.1, 4.3, Fig.4.1).While the maximum percent incidence of disease (14.95%) and per cent disease index (13.64%) was observed in hilly upland ecosystem followed by Coastal belt (14.33% and 13.04% respectively). Whereas, the minimum incidence (11.23%) and severity (10.22%) was noticed in Tunga and Bhadra ecosystems. The survey findings are presented in Table 4.1 and 4.3 and depicted in Fig.4.1

The incidence and severity of rice grain discolouration was recorded during survey conducted across three ecosystems in thirteen districts of Karnataka. The mean per cent disease incidence at district level was ranged from 10.29 to 15.70 and mean per cent disease index was ranged from 8.64 to14.56. Kodagu district has recorded the highest per cent of grain discolouration (15.70%), which was succeeded by Dakshina Kannada district (14.44%), whereas in Davanagere district (10.29%) least incidence was observed. Further, the intensityof disease was maximum in Kodagu district (14.56%) followed by Dakshina Kannada (13.49%), whereas least percent disease index (8.64%) was documented in Ballari district. The detailed data are depicted in Table 4.1.

Table 4.1. Incidence and severity of grain discolouration of rice in hilly, costal and irrigated ecosystems of Karnataka during *Kharif* 2017

						2017			
Ecosystems	Districts	Taluks	Villages	No. of fields	Major genotypes	Disease Incidence (%)	Per cent disease index (PDI)	Mean disease Incidence (%)	Mean per cent disease index (PDI)
Hillyupland	Kodagu	Ponnampet	Hudikeri	3	Hemavathi	16.00	13.33	14.95	13.64
			Srimangala	3	Jaya	13.33	14.70		
			Balele	3	Sona Mahsuri	17.77	16.29		
	District Mean					15.70	14.56		
	Uttara Kannada	Sirsi	Yedurbail	3	KMP105	10.66	08.89		
			Bashi	3	Hemavathi	16.00	14.81		
			Gudnapur	3	Abhilash	13.33	12.59		
	District Mean					13.33	12.09		
Coastalbelts	Dakshina Kannada	Udupi	Barkur	3	Jaya	13.33	11.33	14.33	13.04
			Kundapur	3	KajjiAkki	12.00	12.59		
			Udapi	3	Intan	14.66	13.33		
		Mangaluru	Mudbidari	3	Jyoti	16.00	14.81		
			Beltangdi	3	Kajejaya	13.33	12.59		
			Kankanadi	3	Intan dwarf	17.33	16.29		
	District Mean					14.44	13.49		
	Uttar Kannada	Utta Kannada	Mundugodu	3	Rasi	12.00	10.37		
			Kumata	3	Intan	16.00	14.81		
			Honnavar	3	Jaya	14.66	12.59		
	District Mean					14.22	12.59		
Irrigated Kabini and Kaveri	Chamaraja nagara	Yalandur	Y.K. Mole	3	Super Aman	13.33	11.85	12.16	11.59
			Yariyuru	3	IR-64	12.00	11.11		
			Maddur	3	KRH-4	09.33	10.37		

						2017			
Ecosystems	Districts	Taluks	Villages	No. of fields	Major genotypes	Disease Incidence (%)	Per cent disease index (PDI)	Mean disease Incidence (%)	Mean per cent disease index (PDI)
		Kollegal	Madhuvanahalli	3	Aman	16.00	12.59		
			Gowdalli	3	IR-64	13.33	14.07		
			Uttamballi	3	MTU-1001	10.66	11.11		
	District Mean					12.44	11.85		
	Mandya	Mandya	Mandya	3	IR-64	12.00	12.59		
			Holalu	3	Thanu	10.66	9.63		
			Mallanayankanakatte	3	BR-2655	08.00	8.89		
		Maddur	Devarahalli	3	Jayakrishna	16.00	14.81		
			Doddaarasinakere	3	Aman	13.33	11.85		
			Alemanegate	3	IR-64	12.66	12.59		
		Pandavapura	Pandavapur	3	Aman	10.66	11.11		
			Agatahalli	3	MTU1010	08.00	07.40		
			Alphahalli	3	IR-64	09.33	08.89		
	District Mean					11.18	10.86		
	Mysore	Mysore	Suttur	3	Jyothi	14.66	13.33		
			Basavanapur	3	IR-64	13.33	12.59		
			Horalawadi	3	MTU-1010	10.66	10.37		
	District Mean					12.88	12.07		
Irrigated Tunga and Bhadra	Shivamogga	Shivamogga	Gondhichatttanahalli	3	MTU-1010	09.33	08.89	11.23	10.22
			Harakere	3	BPT 5204	12.00	11.85		
			Holaluru	3	IR-64	10.66	12.59		
	District Mean					10.66	11.11		
	Chikka magaluru	Tarikere	H. Rangapur	3	BPT 5204	14.66	12.59		
			Halasur	3	MTU-1010	13.33	10.66		

						2017			
Ecosystems	Districts	Taluks	Villages	No. of fields	Major genotypes	Disease Incidence (%)	Per cent disease index (PDI)	Mean disease Incidence (%)	Mean per cent disease index (PDI)
			Hanne	3	IR-64	12.00	09.33		
	District Mean					13.33	10.86		
	Davanagere	Channagiri	Kariganur	3	IR-64	09.33	10.66		
			Kasipur	3	BPT 5204	11.33	09.33		
			Arehalli	3	RNR- 15048	10.66	08.91		
		Harihara	Nandigavi	3	BPT 5204	12.66	11.85		
			Kondajji	3	IR-64	08.00	08.89		
			Rajanahalli	3	Jayashree	09.33	09.63		
		Davanagere	Maragondanahlli	3	RNR- 15048	10.66	11.85		
			Kadlebalu	3	BPT 5204	11.33	12.59		
			Avaragolla	3	IR-64	09.33	08.89		
	District Mean					10.29	10.28		
	Ballari	Harapanahalli	Hiremegalegere	3	BPT 5204	12.00	09.63		
			Nitur	3	Kaveri Sona	10.66	08.95		
			Alavagulu	3	MTU-1010	09.33	07.40		
	District Mean					10.66	8.64		
Irrigated Tungabhadra and Upper Krishna Project	Raichur	Sindhanoor	Gorebal	3	BPT 5204	13.33	14.81		
			Sindhanoor	3	Nellor Sona	12.00	11.85	12.62	12.36
			Javalagera	3	Kaveri Sona	11.33	09.63		
	District Mean					12.22	12.09		
	Koppal	Gangavathi	Basapattana	3	BPT 5204	16.00	14.81		
			Heruru	3	Kaveri Sona	14.66	13.33		
			Anegundi	3	Gangavathi Sona	12.59	11.85		
	District Mean					14.41	13.33		
	Ballari	Siruguppa	Siruguppa	3	Kaveri Sona	10.66	09.63		

						2017			
Ecosystems	Districts	Taluks	Villages	No. of fields	Major genotypes	Disease Incidence (%)	Per cent disease index (PDI)	Mean disease Incidence (%)	Mean per cent disease index (PDI)
			B.M.Sugur	3	Nellor Sona	12.00	12.59		
			Balakundi	3	BPT 5204	13.33	14.81		
		Hospete	Amalapur	3	Nellor Sona	9.33	08.81		
			Kampli	3	Gangavathi Sona	10.66	09.63		
			Ramasagara	3	BPT 5204	13.33	12.59		
		Ballari	Emmignur	3	BPT 5204	12.00	11.85		
			Guttiganur	3	Kaveri Sona	13.33	14.81		
			Kottal	3	Gangavathi Sona	12.66	12.59		
	District Mean					11.88	11.93		
	Yadgiri	Shahpur	Hothpete	3	Nellor Sona	10.66	11.85		
			shahapur	3	RNR- 15048	12.00	12.59		
			Gogi	3	BPT 5204	13.33	11.85		
	District Mean					11.99	12.09		

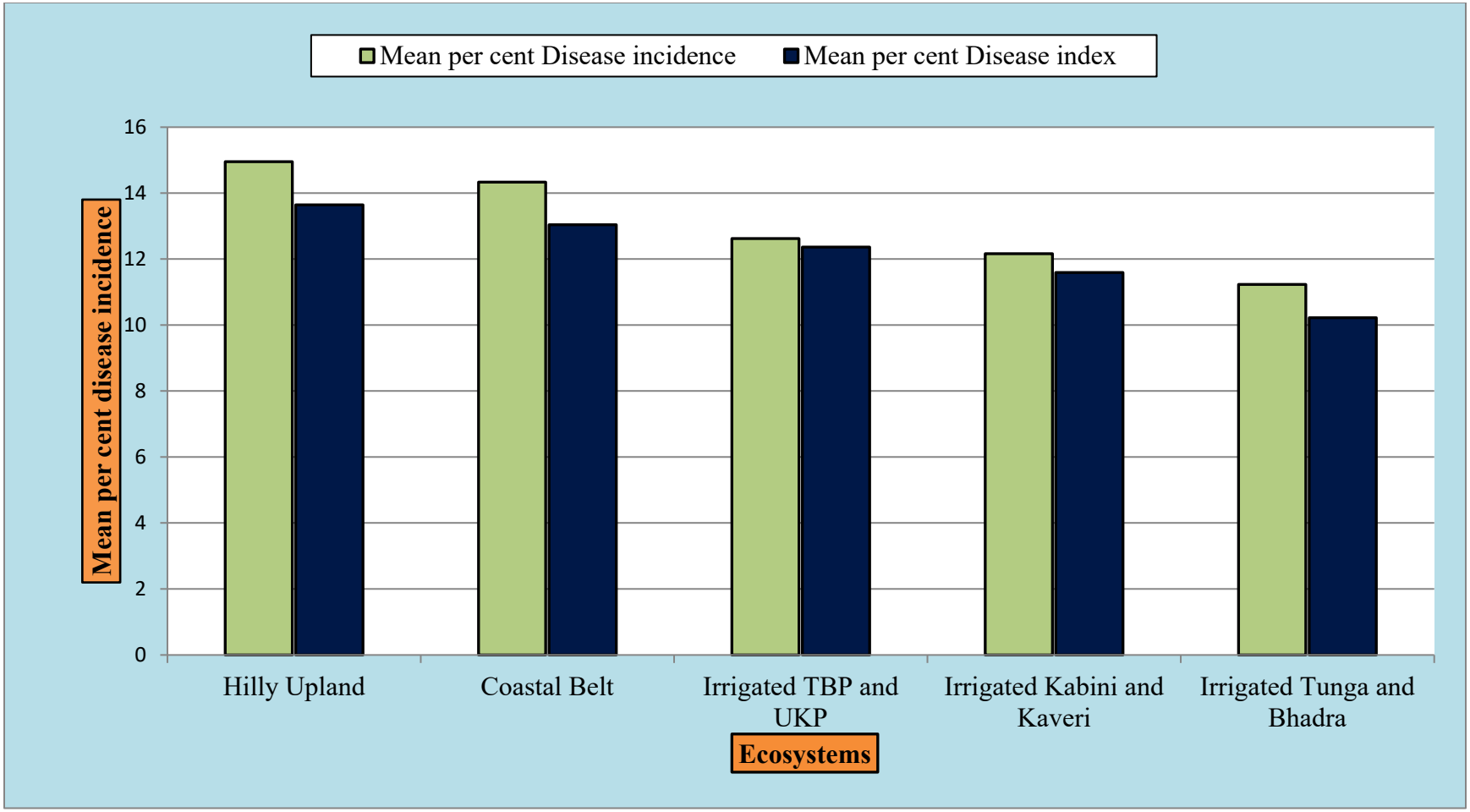


Fig. 4.1. Meaan per cent disease incidence and Mean per cent disease Index of grain discolouration of rice in different ecosystem of Karnataka during *Kharif* 2017

Survey was conducted in sixty-nine villages. The highest incidence of grain discolouration was documented in Balele village (17.77%) in Ponnampet taluk followed by in Kankanadi village (17.33%) and Mudbidarivillage (16.00%) in Mangaluru taluk which are on par with Hudikeri village in Ponnampet taluk, Madhuvinahalli village (16.00%) in Kollegal taluk, Devarahalli village (16.00%) in Maddur taluk,Bashi village (16.00%) in Sirsi taluk and Basapattana village (16.00%) in Ballari taluk. The minimum incidence was found in Mallanayankanakatte village (8.00%) in Mandya taluk which was on par with Kondajji village (8.00%) in Harihara taluk, whereas maximum per cent disease index (16.29%) was observed in Hudikeri village in Ponnampetwhich was on par with Kankanadi village (16.29%) in Mangaluru taluk succeeded by (14.81%) Mudbidari in Mangaluru taluk which was on par with Kumata village (14.81%) in Uttara Kannada, Gorebal village (14.81%) in Sindhanoor taluk and Basapattana village (14.81%) in Ballari taluk.The detailed data are documented in Table 4.1.

Twenty-two rice samples were collected from three ecosystems of Karnataka. The maximum incidence of disease was noticed in BPT-5204 (Sona Mahsuri) (17.77%) followed by Super Aman (16.00%) which was on par with Jayakrishna (16.00%), Hemavati (16.00%) and Jyothi (16.00%). The minimum incidence was noticed in BR-2655 (8.00%) which was on par with MTU-1010 (8.00%) and IR-64 (8.00%). The maximum intensity of disease (16.29%) was documented in BPT-5204 (Sona Mahsuri) succeeded by Intan dwarf (16.29%), Hemavati (14.81%), Kaveri Sona (14.81%), Intan (14.81%) and Jayakrishna (14.81%). Whereas, the minimum severity of disease was recorded in MTU-1010 (7.40%) followed by IR-64 (8.89%) on par with BR-2655 (8.89%), MTU-1010 (8.89%) and KMP-105 (8.89%) (Table 4.1).

During *Kharif* 2018, the incidence and severity of rice grain discolourtion disease was prevalent in three paddy growing ecosystems with mean percent incidence ranged from 11.85 to 15.47 and mean per cent disease index ranged from 11.03 to 13.94, respectively (Table 4.2, 4.3, Fig.4.2). The maximum per cent incidence (15.47%) and severity (13.94%) was recorded in hilly upland region followed by costal belt (15.00% and 13.67 %,) respectively. Whereas the minimum disease incidence and severity was documented in irrigated ecosystem of Thunga and Bhadra (11.85% and 11.03%). The data are depicted in (Table 4.2, 4.3, Fig.4.2).

The grain discolouration was prevalent in all thirteen districts across three ecosystems. The mean per cent disease incidence and index were ranged from (10.95 to 16.14) to (10.31 to14.56), respectively. The maximum per cent discolouration (16.14%) was recorded in Kodagu district followed by Dakshina Kannada district (15.23%) and minimum incidence was documented in Davanagere district (10.95%). Further, the intensity of disease was highest in Dakshina Kannada district (14.56%) followed by Kodagu district (14.31%) and minimum percent disease index (10.31%) was recorded in Davanagere district and relevant data are presented in table 4.2 and plate2.

The maximum incidence of disease (17.77%) was recorded in Kankanadi village in Mangaluru taluk which was on par withGundapur village in Sirisi taluk and Srimangala village in Ponnampet taluk followed by (16.00%) Gowdahalli village in Kollegal taluk, Hudakeri village in Ponnampet taluk,Bashi village in Sirsi taluk,Suttur village in Mysuru taluk,Kumata village in Uttara Kannada taluk and Udupi in Udupi taluk and minimum incidence was documented inKondajji village in Harihara talukand maximum disease index (15.55%) in Udupi in Udupi taluk next to Kundapur village(14.81%) in Udupi taluk, Bashi villagein Sirsi taluk,Kumata village in Uttara Kannada and Guttiganur village in Ballari taluk and minimum disease severity (7.40%) was recorded in Kottal village in Ballari taluk,Agatahalli village in Pandavapur talukand Avaraglla village in Davanagere taluk. The detailed data are documented in Table 4.2.

The results from table 4.3 indicated that, grain discolouration of rice was prevalent in all the three ecosystems. During the survey, 207 rice fields were coveredacross 69 villages from 23 taluks in 15 districts of Karnataka. Mean per cent grain discolourationduring *Kharif* 2017 and 2018 has varied from 11.54 to 15.21 and per cent disease index of 10.62 to 13.79 has been noticed, respectively. Whereas, the maximum per cent disease incidence was noticed in hilly upland (14.95 % and 15.47 %) next to coastal belts (14.33% and 15.00%), Irrigated Tungabhadra project (TBP) and Upper Krishna project (UKP) (12.62% and 12..22%), Kabini and Kaveri (12.16% and 12.22%) and minimum incidence in Irrigated Tunga and Bhadra project (11.23 and 11.85 %), respectively. The highest per cent disease severity was noticed in hilly upland (13.64% and 13.94%) next tocoastal belts (13.04% and 13.67%) followed by

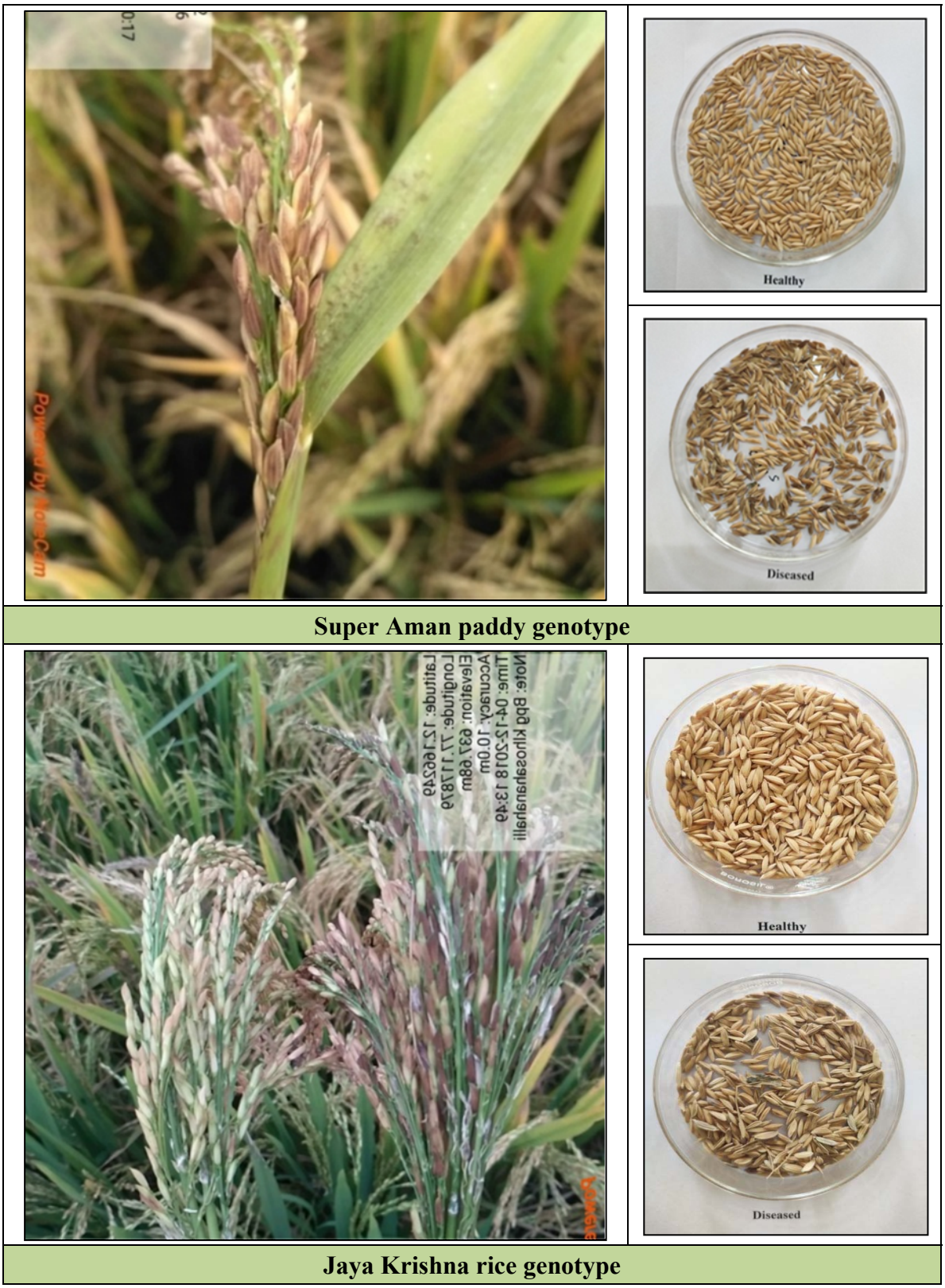
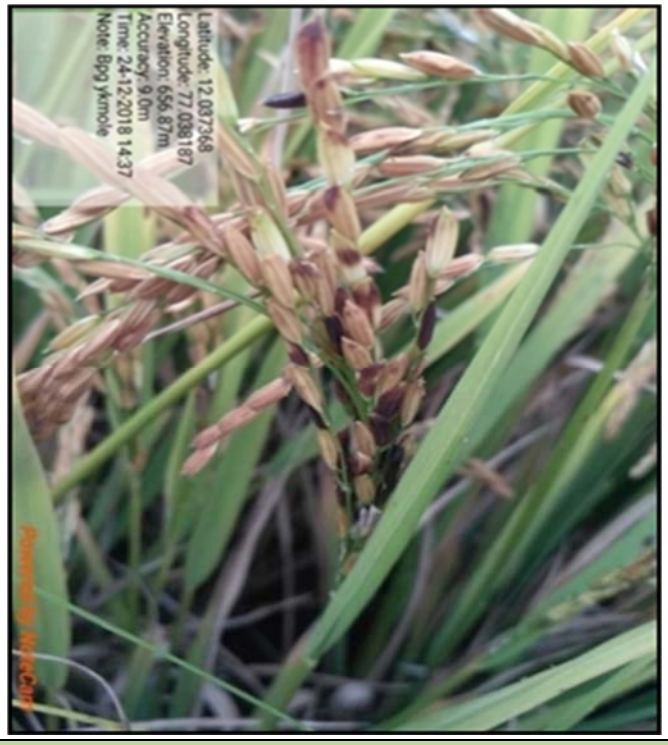


Plate 2a. Incidence and severity of grain discolouration in Super Aman and Jaya Krishna genotypes

Jyothi rice genotype



BPT-5204 rice genotype

Plate 2b. Incidence and severity of grain discolouration in Jyothi and BPT 5204 genotypes

Table 4.2. Incidence and severity of grain discolouration of rice in hilly, costal and irrigated ecosystems of Karnataka during *Kharif* 2018

						2018			
Ecosystems	Districts	Taluks	Villages	No. of fields	Major genotypes	Disease Incidence (%)	Per cent disease index (PDI)	Mean disease Incidence (%)	Mean per cent disease index (PDI)
Hillyupland	Kodagu	Ponnampet	Hudikeri	3	Hemavathi	16.00	16.29	15.47	13.94
			Srimangala	3	Sona Mahsuri	17.77	11.85		
			Balele	3	Jaya	14.66	14.81		
	District Mean					16.14	14.31		
	Uttara Kannada	Sirsi	Yedurbail	3	Jaya	10.66	13.33		
			Bashi	3	Abhilash	16.00	14.81		
			Gudnapur	3	Hemavathi	17.77	12.59		
	District Mean					14.81	13.57		
Coastal belts	Dakshina Kannada	Udupi	Barkur	3	KajjiAkki	14.66	12.59	15.00	13.67
			Kundapur	3	Jaya	13.33	14.81		
			Udapi	3	Intan	16.00	15.55		
		Mangaluru	Mudbidari	3	Kajejaya	15.00	13.33		
			Beltangdi	3	IR-64	14.66	11.11		
			Kankanadi	3	Intan dwarf	17.77	14.66		
	District Mean					15.23	14.56		
	Uttar Kannaa	Uttar Kannada	Mundugodu	3	Jaya	13.33	12.59		
			Kumata	3	Intan	16.00	14.81		
			Honnavar	3	Rasi	15.00	13.33		
	District Mean					14.77	13.57		
Irrigated Kabini and Kaveri	Chamaraja nagara	Yalandur	Y.K.Mole	3	MTU-1010	10.66	11.11	12.21	11.27
			Yariyuru	3	Super aman	15.55	13.33		
			Maddur	3	IR-64	08.88	08.15		

						2018			
Ecosystems	Districts	Taluks	Villages	No. of fields	Major genotypes	Disease Incidence (%)	Per cent disease index (PDI)	Mean disease Incidence (%)	Mean per cent disease index (PDI)
		Kollegal	Madhuvanahalli	3	IR-64	13.33	12.59		
			Gowdalli	3	Jayakrishna	16.00	14.07		
			Uttamballi	3	MTU-1001	11.10	08.89		
	District Mean					12.58	11.35		
	Mandya	Mandya	Mandya	3	Thanu	11.10	08.89		
			Holalu	3	Jaya	13.33	12.59		
			Mallanayankanakatte	3	BR-2655	10.66	11.11		
		Maddur	Devarahalli	3	Jayakrishna	13.33	11.85		
			Doddaarasinakere	3	BR-2655	08.88	10.37		
			Alemanegate	3	Aman	10.66	08.89		
		Pandavapura	Pandavapur	3	IR-64	15.55	13.33		
			Agatahalli	3	BR-2655	11.11	07.40		
			Alphahalli	3	MTU1010	08.88	11.11		
	District Mean					11.50	10.61		
	Mysore	Mysore	Suttur	3	Jyoti	16.00	14.07		
			Basavanapur	3	IR-64	11.10	12.59		
			Horalawadi	3	MTU-1010	10.66	08.89		
	District Mean					12.58	11.85		
Irrigated Tunga and Bhadra	Shivamogga	Shivamogga	Gondhichatttanahalli	3	IR-64	11.10	08.89		
			Harakere	3	BPT 5204	12.00	11.85		
			Holaluru	3	MTU-1010	10.66	11.11		
	District Mean					11.25	10.61	11.85	11.03
	Chikkamagaluru	Tarikere	H. Rangapur	3	Jayashree	14.66	12.59		
			Halasur	3	BPT-5204	15.00	13.33		
			Hanne	3	MTU-1010	12.00	11.11		

						2018			
Ecosystems	Districts	Taluks	Villages	No. of fields	Major genotypes	Disease Incidence (%)	Per cent disease index (PDI)	Mean disease Incidence (%)	Mean per cent disease index (PDI)
	District Mean					13.88	12.34		
	Davanagere	Channagiri	Kariganur	3	RNR-15048	11.10	10.66		
			Kasipur	3	BPT 5204	12.00	12.59		
			Arehalli	3	IR-64	10.66	08.89		
		Harihara	Nandigavi	3	RNR- 15048	12.66	11.85		
			Kondajji	3	MTU-1010	08.00	08.89		
			Rajanahalli	3	BPT 5204	13.33	11.11		
		Davanagere	Maragondanahlli	3	RNR- 15048	10.66	08.89		
			Kadlebalu	3	BPT 5204	11.33	12.59		
			Avaragolla	3	IR-64	08.88	07.40		
	District Mean					10.95	10.31		
	Ballari	Harapanahalli	Hiremegalegere	3	MTU-1010	10.66	08.89		
			Nitur	3	BPT 5204	12.00	11.11		
			Alavagulu	3	Kaveri sona	11.33	12.59		
	District Mean					11.33	10.86		
Irrigated Tungabhadra and Upper Krishna Project	Raichur	Sindhanoor	Gorebal	3	Nellor Sona	11.10	11.85	12.22	11.35
			Sindhanoor	3	Gangavathi Sona	10.86	11.11		
			Javalagera	3	BPT 5204	13.33	10.89		
	District Mean					11.76	11.28		
	Koppal	Gangavathi	Basapattana	3	BPT 5204	15.00	13.33		
			Heruru	3	Gangavathi Sona	11.11	10.89		
			Anegundi	3	Kaveri Sona	13.33	12.59		
	District Mean					13.14	12.27		
	Bellari	Siruguppa	Siruguppa	3	Kaveri Sona	11.11	08.89		
			B.M.Sugur	3	Nellor Sona	12.00	12.59		

						2018			
Ecosystems	Districts	Taluks	Villages	No. of fields	Major genotypes	Disease Incidence (%)	Per cent disease index (PDI)	Mean disease Incidence (%)	Mean per cent disease index (PDI)
			Balakundi	3	BPT 5204	13.33	11.11		
		Hospete	Amalapur	3	Kaveri Sona	09.33	08.89		
			Kampli	3	Nellor Sona	10.66	09.63		
			Ramasagara	3	BPT 5204	11.10	08.89		
		Ballari	Emmignur	3	Nellor Sona	12.00	11.85		
			Guttiganur	3	BPT 5204	15.55	14.81		
			Kottal	3	Kaveri Sona	08.88	07.40		
	District Mean					11.55	10.45		
	Yadgiri	Shahpur	Hothpete	3	Kaveri Sona	09.33	11.85		
			Shahapur	3	Nellor Sona	12.00	08.89		
			Gogi	3	BPT 5204	15.00	13.33		
	District Mean					12.11	11.35		

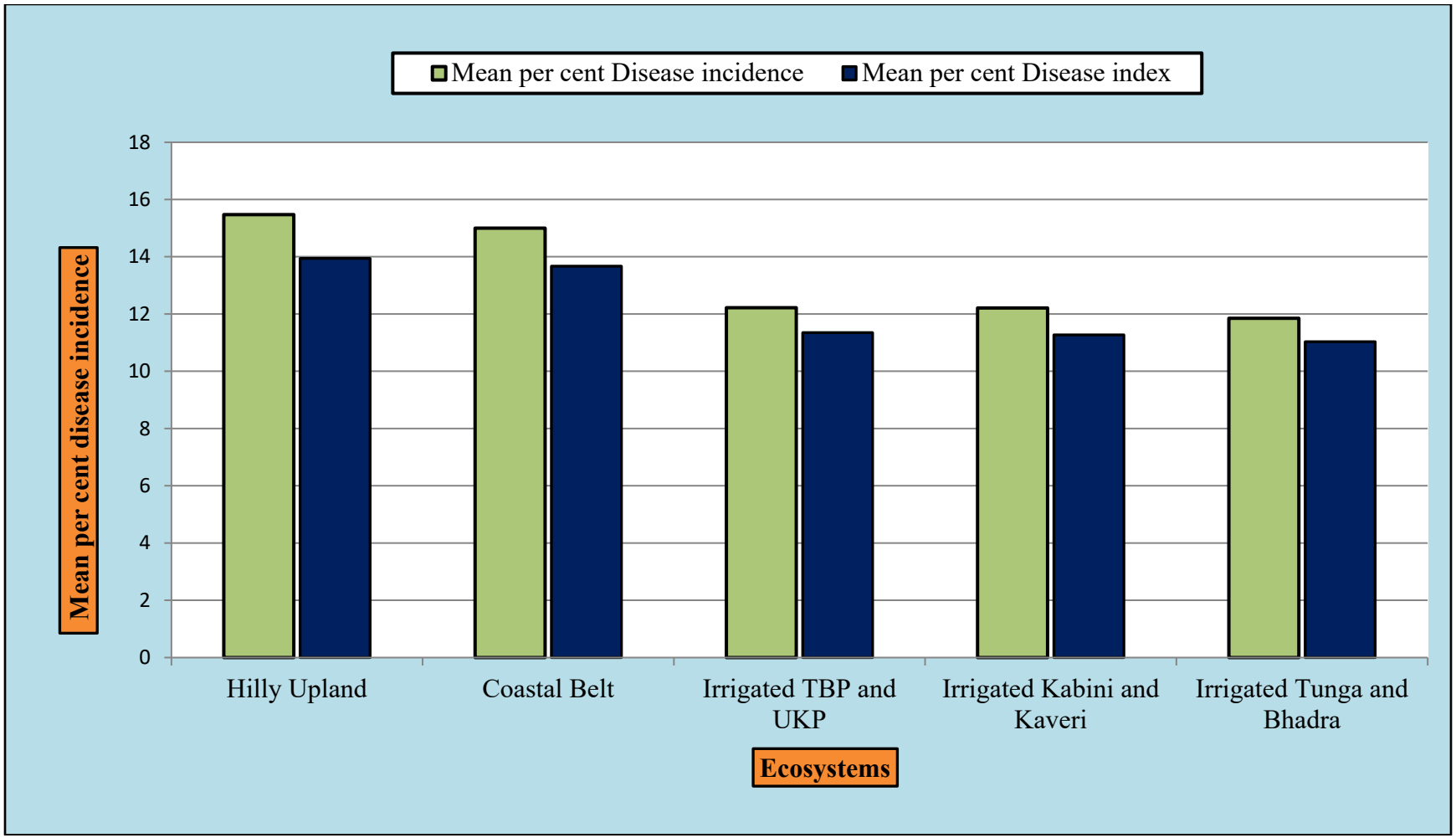


Fig.4.2. Mean per cent disease incidence and Mean per cent disease Index of grain discolouration of rice in different ecosystem of Karnataka during *Kharif* 2018

Tungabhadra project (TBP) and Upper Krishna project (UKP) (12.36% and 11.35%) next in irrigated Kabini and Kaveri (11.59% and 11.27%). Whereas, minimum disease intensity was recorded in irrigated ecosystem of Tunga and Bhadra was (10.22% and 11.03%) (Table 4.3 and Fig.4.3).

Twenty-two rice samples of different varieties / hybrids were collected from three ecosystems *viz.*, Hilly, Costal, and irrigated ecosystem of Kabini, Kaveri, Tunga, Bhadra, Tungabhadra and Upper Krishna project. The highest disease incidence was recorded highest in BPT-5204 (Sona Mahsuri) (17.77%) which was on par with Hemavati (17.77%) and Intan dwarf (17.77%) followed in Jayakrishna (16.00%), Abhilash 16.00%), Intan (16.00%), KajjiAkki (16.00%) and Jyoti (16.00%). Whereas, least incidence was observed in MTU-1010 (8.00%) followed by 8.88% in BR-2655 and IR-64. The disease maximum index was recorded in Abhilash variety (16.29%) followed byIntan (15.55%). Whereas, least incidence was observed in BR-2655 (7.40%), IR-64 (7.40%) and Kaveri Sona (7.40%). (Table 4.1 and Table 4.2).

Among three ecosystems surveyed during *Kharif* 2017 and 2018, the higher average per cent disease incidence (15.21%) and severity (13.79%) was observed in hilly ecosystem followed by coastal ecosystem (14.66% and 13.35%,) respectively (Table 4.3). The rice varieties cultivated in two ecosystems *viz.*, Jaya, KajeJaya, KMP105, Jyothi, Abhilash, Hemavati and Intan *etc*.are medium coarse grain and generally showed moderately resistant reaction to grain discolouraion but when these varieties were exposed to rainy condition, lower temperature and more relative humidity during crop growth they became susceptible to grain discolouration. Whereas, mean average disease incidence (12.42%) and severity (11.85%) was observed in Tungabhadra and Upper Krishna Project ecosystem followed by Kabini and Kaveri were 12.19 and 11.43 per cent, respectively. The lowest mean disease incidence (11.54%) and severity (10.62%) was showed in Tunga and Bhadra ecosystem (Table 4.3). The popular varieties under cultivation in these ecosystems *viz.*, BPT 5204, Nellor Sona, Kaveri Sona, Gangavathi Sona, RNR- 15048, Jayakrishna, Super Aman, Jayashree, IR-64, MTU-1010 and Thanu*etc*., majority of these varieties are fine quality rice and these were susceptible to grain discolouration but showed lesser incidence of disease in three ecosystems. Though

Table 4.3. Mean disease incidence and severity of grain discolouration of rice in different ecosystems of Karnataka surveyed during *Kharif* 2017 and 2018

Ecosystems	No. of districts covered	No. of taluks covered	No. of villages covered	No. of fields covered	Major genotypes collected	Disease Incidence (%)			Per cent disease index (PDI)		
						2017	2018	Mean	2017	2018	Mean
Hilly upland	2	2	6	18	Jaya, KajeJaya, KMP105, Jyothi, Abhilash, Hemavati and Intan	14.95	15.47	15.21	13.64	13.94	13.79
Coastal belts	2	3	9	27	Jaya, Jyoti, Intan, Intan dwarf	14.33	15.00	14.66	13.04	13.67	13.35
Irrigated Kabini and Kaveri	3	6	18	54	IR-64, MTU-1010, MTU-1001, Super Aman, KRH-4, Thanu, Jaya, BR-2655, KRH-4, Jayakrishna	12.16	12.22	12.19	11.59	11.27	11.43
Irrigated Tunga and Bhadra	4	6	18	54	RNR-15048, Jayashree, BPT 5204, IR-64, MTU-1010	11.23	11.85	11.54	10.22	11.03	10.62
Irrigated Tungabhadra and Upper Krishna project	4	6	18	54	BPT5204, RNR- 15048 Gangavati Sona, Nellor Sona, Kaveri Sona	12.62	12.22	12.42	12.36	11.35	11.85
Total	15	23	69	207	-						

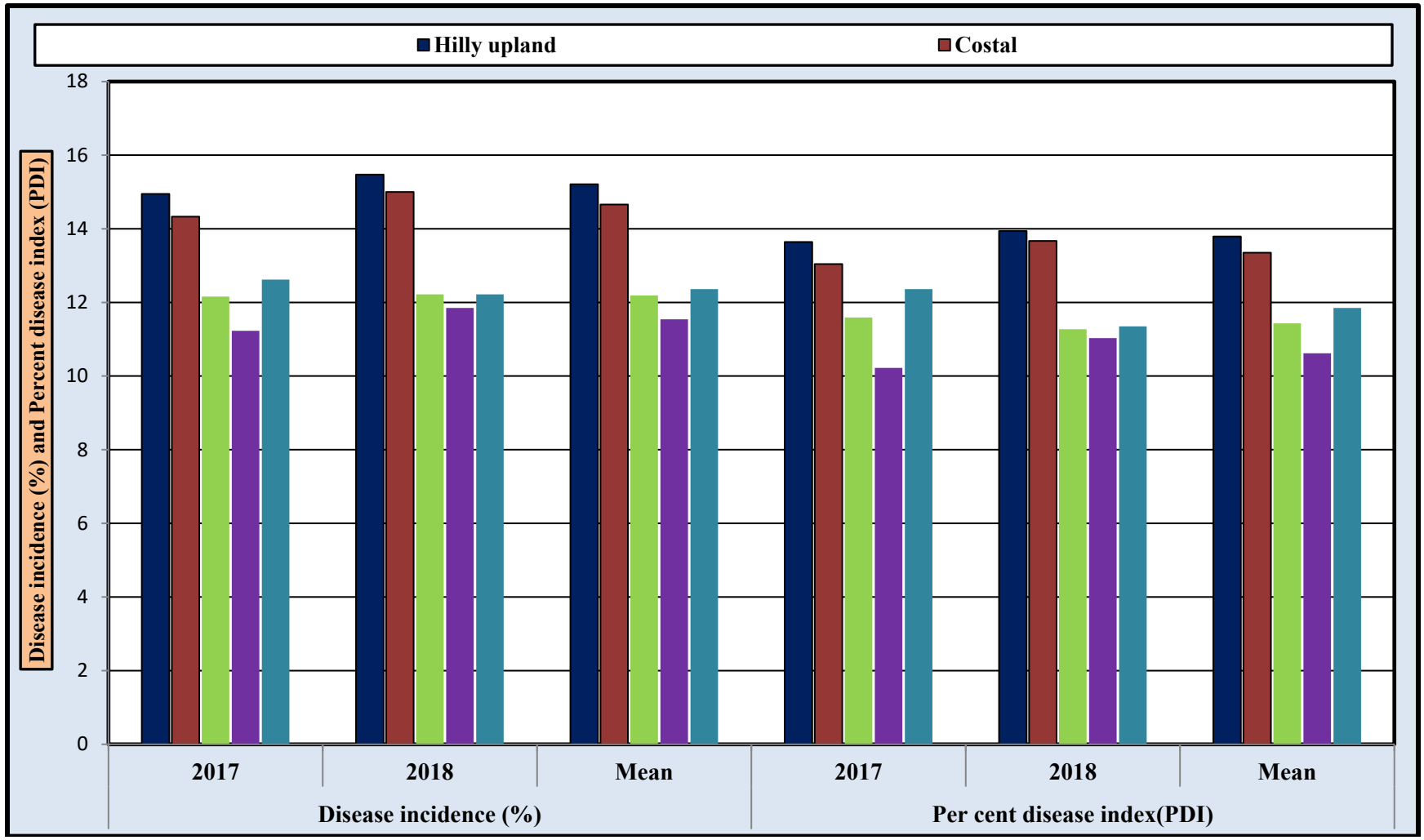


Fig 4.3. Disease incidence and severity of rice grain discolouration during 2017 and 2018 (Mean) in different rice ecosystems of Karnataka

these varieties are susceptible to grain discolouration but in these ecosystems generally more quantum of nitrogen-based fertilizers was used three times higher than the recommended dosage (100 N). But the crop has exposed to higher temperature, lower humidity and lesser number of rainy days during growth period, besides in these ecosystem farmers are usually taking plant protection measures at every 15 days intervals lead to lower incidence of diseases and insect pests. These results are in accordance with the Sumangala *et al*., (2010) and Saifulla (1997).

These survey results are compared with previous reports from Saifulla*et al.*, (1997) who reported that the highest incidence of grain discolouration of rice was documented in hilly region from 5 to 50 per cent folloed by coastal region which varied from 0 to 50 per cent.Whereas, recorded 0 to 5 per cent incidence in summer and 0 to 25 per cent in plain region during survey carried out during *Kharif* 1996 and 1997 in Karnataka. The incidence of rice grain discolouration was assessed during 1989 and 1990 in Hamirpur, Kangra Bilaspur, Kullu, Sirmour, Chamba, Mandi, Unaand Solan districts of Himachal Pradesh. Highest grain discolouration was documented at Rahlu in Kanga district (88.12%) and minimum was in Una district (7.60%) (Sharma and Vaid, 1990). The incidence of rice grain discolouraion was assessed on weight basis as well as number basis in all the samples which were procured from four districts in Andhra Pradesh. The highest incidence was noticed in West Godavari district samples and varied from 21.91 % to 27.32 % on weight basis and from 22.74 % to 28.88 % on grain number based analysis which were followed by Krishna district (23.02 % to 28.62 % and 24.34 % to 30.35%), Guntur district (22.58 % to 28.76 % and 24.57% to 30.46 %), and Nellore district (22.88% to 28.74% and 25.05% to 30.81%), respectively (Divya, 2015).

The preliminary investigations conducted in *Kharif* 2017 and 2018 revealed that SonaMahsuri (BPT 5204) was commonly cultivated in Tungabhadra and Upper Krishna ecosystem, Tunga and Bhadra ecosystem and Part of hilly ecosystem, which was prone to grain discolouration. In general, the disease incidence varied from 9.33 to 17.77 per cent in different ecosystems. This variety has recorded higher disease incidence in Kodugu district (17.77%) followed by Ballari (16.00%) and Koppal districts (15.55%), respectively. Whereas, least disease incidence was observed in BR-2655 (7.40%) and IR-

64 (7.40%). These results showed that the fine grain rice varieties *viz*., BPT 5204 and Jayakrishna were showed highly prune to grain discolouraion and medium grain varieties *viz.*, BR-2655 and IR-64 were less prone to grain discolouration in the ecosystems where these varieties popularly cultivated. These results were supported in our field experiment conducted on screening of rice genotypes during *Kharif* 2017 and 2018. The similar results byImran Arshad *et al.* (2009) are in agreement withresults and who reported thatin hilly area of Pakistan, the rice grain discolouration disease was more severe in *Kharif* season as compared to summer season and became a serious threat. The health status of rice grains was analyzed from 287 seed samples procured from 20 cultivars in Tamil Nadu. The incidence of disease varied from 1.39 to 58.89 per cent. Gopalakrishnan *et al*. (2010) and Sumangala *et al.* (2010) surveyed to assess the incidence and severity of rice grain discolouration in North Eastern districts likeYadgir, Koppal and Raichur in Karnataka. The disease incidence and severity were 10.34 and 8.69, 11.27 and 9.05, 8.39 and 10.70 in Raichur, Yadagir and Koppal districts, respectively.

During *Kharif* 2017 and 2018, roving survey was carried out in three rice growing ecosystems of Karnataka *viz*., hilly, costal and irrigated *viz.*, Kabini and Kavari, Tunga and Bhadra, Tungabhadra and Upper Krishna project. Results from the table 4.4 and fig.4.14 clearly indicated that, the rice grain discolouration was present in the three ecosystems at different severity. In the three ecosystems, short, medium and long duration rice genotypes were cultivated but per cent rice grain discolourationwas varied with the duration of genotypes and quality of grain. Highest average mean per cent disease incidence and intensity was noticed in long duration genotypes in hilly upland (16.25 % and 14.54 %) followed by costal (15.44 % and 13.94 %), Tungabhadra and Upper Krishana (13.71 % and 12.75 %) , Tunga and Bhadra (12.47 % and 11.69 %) and Kabini and Kaveri (11.33%) and except severity was noticed higher in medium duration genotypes (11.50%).

In hilly upland, the rice genotypes being cultivated weremajorly as long duration than the medium and short duration. The highest the mean disease incidence of 17.77 per cent and severity of 14.70 per cent of rice grain discolouration was noticed in Sona Mahsuri followed in Hemavathi (16.00 % and 14.81 %) and Jaya (14.99 % and 14.75), respectively. Short, medium and long duration rice genotypes were cultivated in costal

ecosystem, the highest mean average disease incidence (15.44 %) and severity (13.94 %) was noticed in long duration genotypes than medium (15.33 %) and (13.96 %) and short duration (13.50 %) and (10.39 %), respectively. Among rice genotypes collected, the highest mean per cent disease incidence (17.33 %) and severity (15.47 %) was noticed in Intan dwarf as a long duration genotype followed in Jyothi (16.00 %) and (14.81 %) as a medium duration on par with Intan (15.66 % and 14.81 %), respectively.

Among three irrigated ecosystems *viz*., Kabini and Kaveri, Tunga and Bhadra, Tungabhadra and Upper Krishna project the disease incidence and intensity of rice grain discolouration was existed in all type of short, medium and long duration genotypes cultivated in all the three ecosystems. The highest mean average disease incidence (13.75 %) and severity (12.75 %) was noticed in long duration genotypes in Tungabhadra and Upper Krishna projects followed by (12.79 % and 11.69 %) in long duration genotype in Tunga and Bhadra, (11.33 %) disease incidence in long duration and (11.50 %) severity in medium duration genotype in genotype in Kabini and Kaveri. Among the samples of genotypes collected, the highest mean incidence ofdisease (15.33 %) and mean disease intensity (13.88 %) was noticed in Jayakrishna followed by Jyothi (15.33 %) and (13.70%) and BPT 5204 (13.71 %) and (12.75 %), respectively. The genotypes *viz*., Jayakrishna, Super Aman, Nellor Sona, Kaveri Sona, Gangavathi Sona and BPT- 5204, were cultivated across three irrigated ecosystems were medium and long duration genotypes beside all of them were fine quality rice and showed higher disease incidence and severity as compared to coarse grain genotypes *viz*., MTU 1010, IR 64, MTU- 1001, Thanu and BR-2655 as short, medium and long duration genotypes.

Across the three ecosystem *viz*., hilly upland, costal belts and irrigated belt of Kabini, Kaveri, Tunga, Bhadra, Tungabhadra and Upper Krishna project short, medium and long duration rice genotypes were cultivated but the higher incidence of grain discolouration was noticed in long as well as medium duration genotypes with fine quality rice than the short duration genotypes. It was mainly because of the long and medium duration genotypes were exposed more to biotic and abiotic stresses. These research results are in agreement with the Saifulla et *al.* (1997), Sumangala *et al*. (2010) and Divya, 2015).

Table 4.4. Incidence and severity of rice grain discolouration in short, medium and long duration genotypes collected from different ecosystems of Karnataka during 2017 and 2018

Sl. No.	Ecosystems	Duration	Samples collected	Disease Incidence (%)				Per cent disease index (PDI)			
				2017	2018	Mean	Mean average	2017	2018	Mean	Mean average
1	Hilly upland	Short (120-125)	-	-	-	-	-	-	-	-	-
		Medium (130-135)	-	-	-	-	-	-	-	-	-
		Long (140-165)	Jaya	13.33	14.66	14.99	16.25	14.70	14.81	14.75	14.54
			Hemavathi	16.00	16.00	16.00		13.33	16.29	14.81	
			Sona Mahsuri	17.77	17.77	17.77		16.29	11.85	14.07	
2	Costal belts	Short (120-125)	Rasi	12.00	15.00	13.50	13.50	10.37	-	-	10.37
		Medium (130-135)	Jyothi	16.00	-	16.00	15.33	14.81	-	14.81	12.96
			IR-64	14.66	14.66	14.66		-	11.11	11.11	
		Long (140-165)	Jaya	13.99	13.33	13,66	15.44	11.33	13.70	12.51	13.93
			Intan	15.33	16.00	15.66		14.07	15.55	14.81	
			Intan dwarf	17.33	17.33	17.33		16.29	14.66	15.47	
			Kajejaya (Local)	13.33	15.00	14.16		12.59	13.33	12.96	

Sl. No.	Ecosystems	Duration	Samples collected	Disease Incidence (%)				Per cent disease index (PDI)			
				2017	2018	Mean	Mean average	2017	2018	Mean	Mean average
	Irrigated										
3a	Kabini and Kaveri	Short (120-125)	MTU 1010	09.33	10.06	9.69	9.69	8.88	10.37	9.62	9.62
		Medium (130-135)	IR-64	12.10	12.21	12.15	10.25	11.97	11.66	11.81	11.50
			Thanu	10.66	11.10	10.88		9.63	8.89	9.26	
			Super Aman	13.33	13.10	13.21		11.85	11.11	11.48	
			Jyothi	14.66	16.00	15.33		13.33	14.07	13.70	
			Jayakrishna	16.00	14.66	15.33		14.81	12.96	13.88	
			KRH-4	9.33	-	9.33		10.37	-	10.37	
			MTU 1001	10.66	11.10	10.88		11.11	8.89	10.00	
		Long (140-165)	BR 2655	8.00	10.66	9.33	11.33	8.89	9.62	9.25	10.92
			Jaya	-	13.33	13.33		-	12.59	12.59	
3b	Tunga and Bhadra	Short (120-125)	MTU 1010	10.66	8.39	9.52	10.14	8.98	10.00	9.49	9.95
			RNR- 15048	10.66	10.88	10.77		10.38	10.46	10.42	
		Medium (130-135)	IR-64	9.99	10.21	10.10	11.02	10.07	8.39	9.23	10.37
			Jayashree	9.33	14.66	11.99		9.63	12.59	11.11	
			Kaveri Sona	10.66	11.33	10.99		8.95	12.59	10.77	
		Long (145-165)	BPT 5204	12.33	12.61	12.47	12.47	11.30	12.09	11.69	11.69
3c	Tungabhadra and Upper Krishna project	Short (120-125)	RNR 15048	12.00	-	12.00	12.00	12.59	-	12.59	12.59
		Medium (130-135)	Nellor Sona	10.99	11.55	11.27	11.36	11.27	10.96	11.11	11.09
			Gangavathi Sona	11.97	10.98	11.47		11.35	11.00	11.17	
			Kaveri Sona	12.49	10.21	11.35		11.85	10.18	11.01	
		Long (145-165)	BPT 5204	13.55	13.88	13.71	13.71	13.45	12.06	12.75	12.75

4.2 Categorization of discoloured grain

By visual observations, the incidence and severity of grain dicolouration of rice was recorded based on symptoms noticed on grains of various rice genotypes and measured using 0-9 standard evaluation system scale given byIRRI (2013). Thevariation in symptoms among rice genotypes were observed in terms of colour as well as the extent of surface area discoloured on grains. The varied colour*viz.*, light brown, brown, dark brown, necrotic spot, black discolouration, slight pink, tip discolouration and depressed lesion. The extent of surface area observed is few dots, small patches, large discoloured patches and complete discoloured surface.

For categorization of discoloured grains, twenty-two rice genotypes were collected from three major rice growing ecosystems of Karnataka. Discolouration was commonly prevailed in all the genotypes which were tested. Further, the grain samples were categorized as apparently healthy, discoloured and chaffy grains. The observations on grain discolouration were recorded in Table 4.5 and shown in Plate 3. The data recorded that the per cent grain discolouration varied from 8.00 to 59.00. The maximum grain discolouration (59%) was noticed in BPT 5204 and which wason par with Jayashree and followed by Super Aman (57%) and Jyothi (53%), whereas the least discolouration was recorded in Jaya (8%). These research result findings are in acceptance with Sharma *et al.* (1987), Mishra and Vir (1991), Sinha (1999), Negi and Das(2003) and Varsha shekhar (2018).They reported thatthe incidence of rice seed discolouration in TN-1 (6.6%), IR-8 (19%), PR-106 (23%), Boro (36.75%).Pant Dhan-16 (40%),), Saket (45.3%), RAU-1-16-48 (48%) Manhar (52.8%), Narendra-80 (54.7%), BPT-5204 (57%), Jarga (58.7%) and Rajshree (69%) genotypes.

4.3 Fungal mycoflora associated with rice grain discolouraiton and their characteristics

Total twenty tworice samples of infected with grain discolorations were collected from three ecosystem *viz*, hilly upland, costal and irrigated Kabini, Kaveri, Tunga, Bhadra, Tungabhadra and Upper Krishna Project. These samples were maintained at Plant health clinic laboratory, ICAR Krishi Vigyan Kendra, Chamarajangara. Further, the

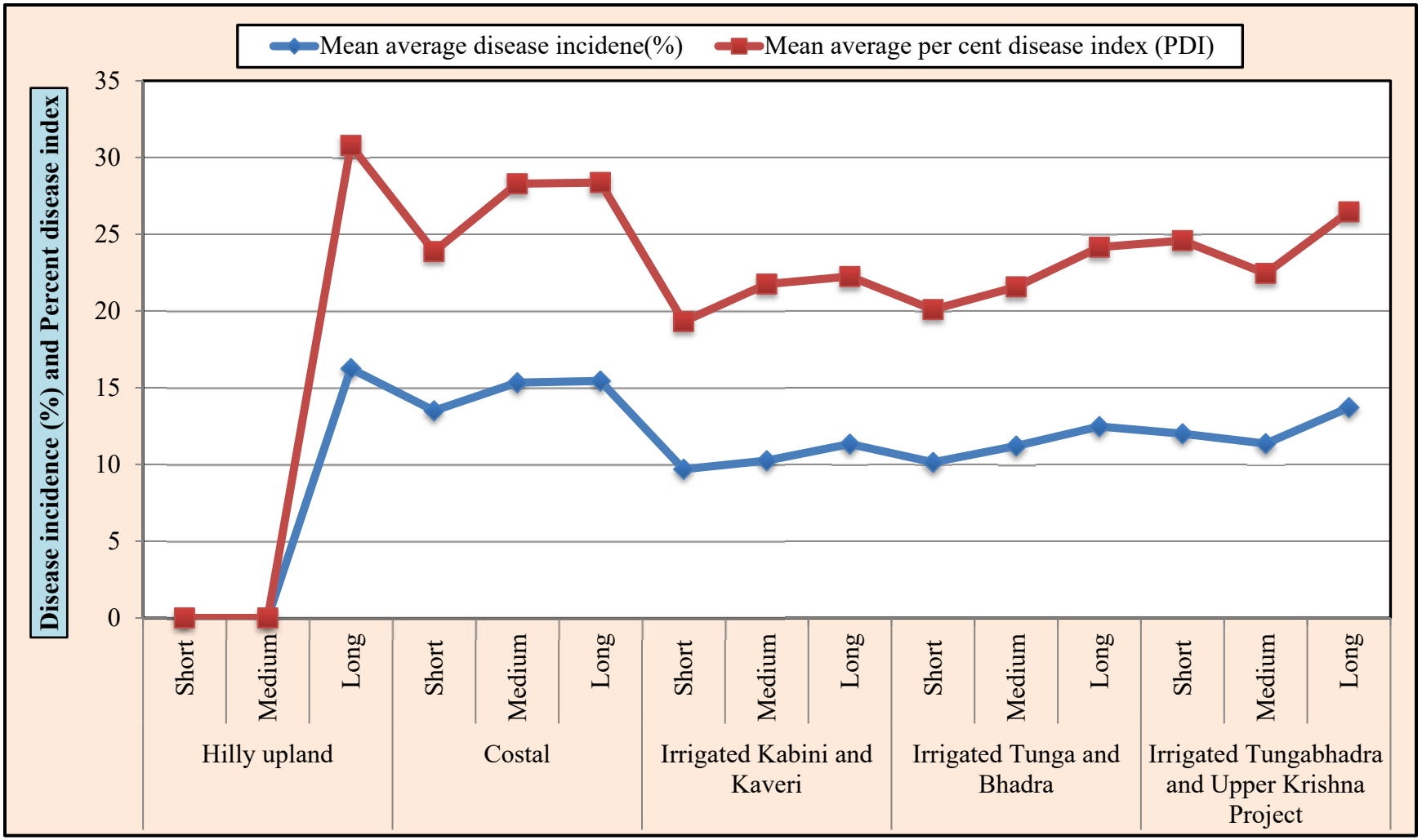


Fig.4.4. Mean average per cent disease incidence and per cent disease index in short, medium and long duration rice genotypes in different ecosystem in Karnataka

Table 4.5 Categorization of grain discolouration incidence in different rice genotypes collected from three ecosystem of rice based on lesion size

Sl. No.	Name of the genotype	Total number of seeds	Lesion			Chaffiness	Discoloured grains (%)	Apparently healthy grains	Symptoms
			A	B	C				
1	IR-64	400	39	29	15	13	24	304	Light brown, brown, dark brown and necrotic spot at tip
2	BR 2655	400	19	16	10	3	12	352	Necrotic spot at tip and enlarge towards middle and light brown
3	Jyothi	400	69	58	46	39	53	188	Light brown, brown, dark brown and black discolouration
4	Super Aman	400	79	71	48	30	57	172	Dark brown and black discolouration
5	Jayashree	400	75	67	51	43	59	164	Black discolouraiton and dark brown
6	Jayakrishana	400	53	51	26	14	36	256	Black and dark brown
7	Gangavathi Sona	400	38	29	19	10	24	304	Light brown, brown and dark brown
8	Jaya	400	10	10	9	3	8	368	Necrotic spot at tip enlarge towards middle and light brown
9	Thanu	400	38	36	26	16	29	284	Brown at tip and light brown
10	MTU- 1001	400	45	34	29	4	28	288	Necrotic spot at tip, light brown, brown and dark brown
11	MTU-1010	400	37	26	19	2	21	316	Light brown, brown, dark brown and necrotic spot at tip
12	KRH-4	400	32	23	17	4	19	324	Necrotic spot at tip and light bron

Sl. No.	Name of the genotype	Total number of seeds	Lesion			Chaffiness	Discoloured grains (%)	Apparently healthy grains	Symptoms
			A	B	C				
13	KMP-105	400	26	17	8	5	14	344	Light brown and brown
14	Abhilash	400	59	41	36	8	36	256	Black and dark brown discolouration
15	Hemavathi	400	61	55	31	5	38	248	Light brown and brown
16	BPT-5204	400	81	68	33	54	59	164	Light pink, light brown, brown, dark brown and black discolouration
17	RNR-15048	400	41	35	22	14	28	288	Necrotic spot at tip, light brown and brown discolouration
18	Nellur Sona	400	40	29	28	19	29	284	Brown, dark brown and black discolourtion
19	Kaveri Sona	400	39	28	19	6	23	308	Dark brown and black discolouration
20	Intan	400	33	19	17	7	19	324	Black and dark brown
21	Kaje Jaya	400	19	14	9	2	11	356	Necrotic spot at tip and dark brown
22	Rasi	400	31	19	17	5	18	328	Whole grain dark brown, black and necrotic spot at tip

A = Small (< 25 % area in discoloured grains); B = Medium (26 to 50 % area in discoloured grains); C = Large (> 50 % area in discoloured grains).

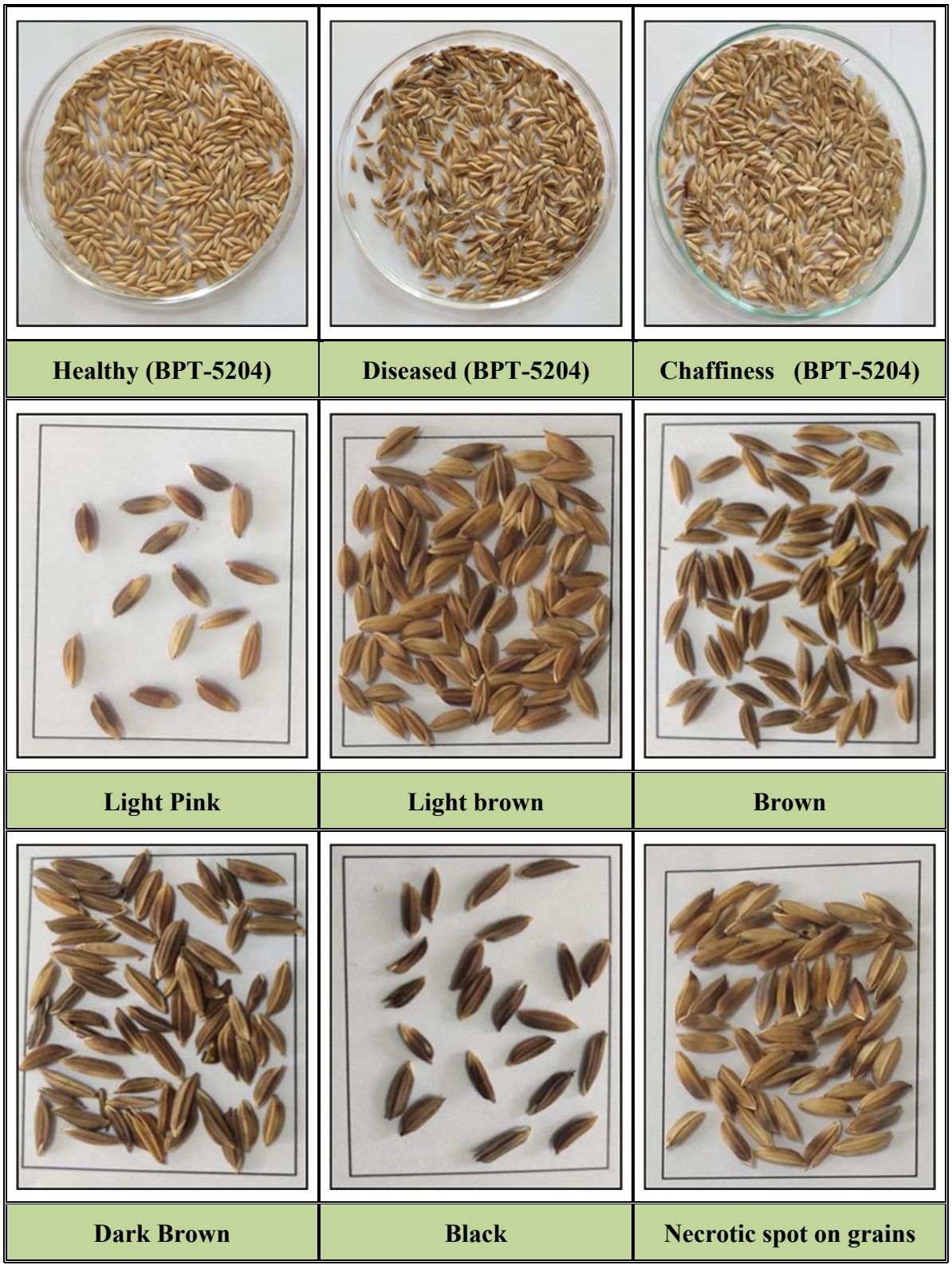


Plate 3. Categorization of discoloured grains samples of different rice genotypes based on symptoms of appearance and lesion size

pathogens were isolated from these samples and their morphological and cultural characteristics were studied. Important morphological characteristics observed were shape, size, and mycelial colour, shape of conidia and arrangement of spores. The cultural characteristics *viz*., growth pattern, colour of mycelium and observed mycelial colour under lower side in PDA media at interval of every two daysand these details are presented in Table 4.6, Plate 4.

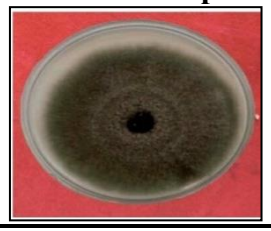
4.4 Detection of pathogens associated with discoloured grains by various method

The establishment of healthy crop and getting higher yield is mainly depends on the quality of seed used. Hence, seed is the main component and it should be free from the pathogens. Grain discolouration associated with various pathogens, these pathogens are reducing the seed quality. The extent of damage on the seed is mainly depends on which position pathogen was presented. Some of the pathogens are present on seed glumes or kernals, or both means they are present internally or externally. But the nature of expression and level of damage is varying according to seasons, locality, type of cultivar used and host physiology etc., If no attention is given at earliest, it causes serious problem for the rice crop. Henceforth, there in need to isolate and detect the pathogens by various methods, it would be helpful for the management of disease.

4.4.1 Isolation and observation of associated pathogen with rice grain discolouration by blotter paper test

The discoloured rice grain samples (22) were acquired from three ecosystems. These discolourd samples were used for isolation byblotter paper method and detected the associated pathogens. The pathogenic mycoflora detected from discoloured rice grains were *Fusarium* sp., *Helminthosporium* sp., *Curvularia* sp., *Alternaria* sp. *Aspergillus* sp., *Cladosporium sp*., *Phoma sp*. and *Magnaporthe oryzae*. Besides that, the per cent distributions of the fungi associated with discolored rice grain samples of twenty-two genotypes were also detected and it varied from 27 to 78 per cent. Recorded highest per cent distribution of mycoflora with the variety BPT-5204 (78%) followed by Jayakrishna (77 %) and Jyothi (72%), whereas the least per cent association of mycoflora was noticed in variety Rasi (27%). (Table 4.7, Fig. 4.5, Plate 5). In Blotter paper method, a total number of 8 mycoflora species viz., *Helminthosporium* sp., *Curvularia* sp.,

Table 4.6. Fungal mycoflora associated with rice grain discolouration samples and their morphological and cultural characters

Mycoflora	Morphological character		Cultural character
***Fusarium* sp.** 	Hyphae	Branched and septate.	White fluppymyceial growth later it is covering the entire plate. These powdery appear due to formation of micro conidia. Later observed pink colour on upper side and lower side of plate appears dark pinkish. 18.21 mm of radial growth was observed after 48 hours.
	Conidiophores	Spore bearing structure holding laterally micro conidia in chain	
	Conidia	Hyaline, 1-2 celled and fusiform to ovate in shape	
***Curvularia* sp.** 	Conidiophore	Errected and scattered with blockish appearance	Dark brownish and lower side of the plate appears dark whitish black in colour.16.12 mm of radial growth was observed after 48 hours
	Conidia	Light to dark brown, curve shape and also looks boat shaped, arranged in group with terminal position and laterally born.	
***Alternaria* sp.** 	Mycelia	Well developed, branched, thin, hyaline and grayish brown	Grey coloured colony and lower side of plate looks dark grey to brownish coloured. 17.36 mm of radial growth observed after 48 hours
	Hyphae	Colour appeared like straw to dark brown.	
	Conidia	Fusiform, three to five transverse septa,long terminal appendages	
	Conidiophores	Swollen apically	
Heliminthosporium sp. 	Hyphae	Branched, darker.	17.32 mm of radial growth observed after 48 hours. Colony appears whitish brown and lower side of the plate looks dark brownish colour

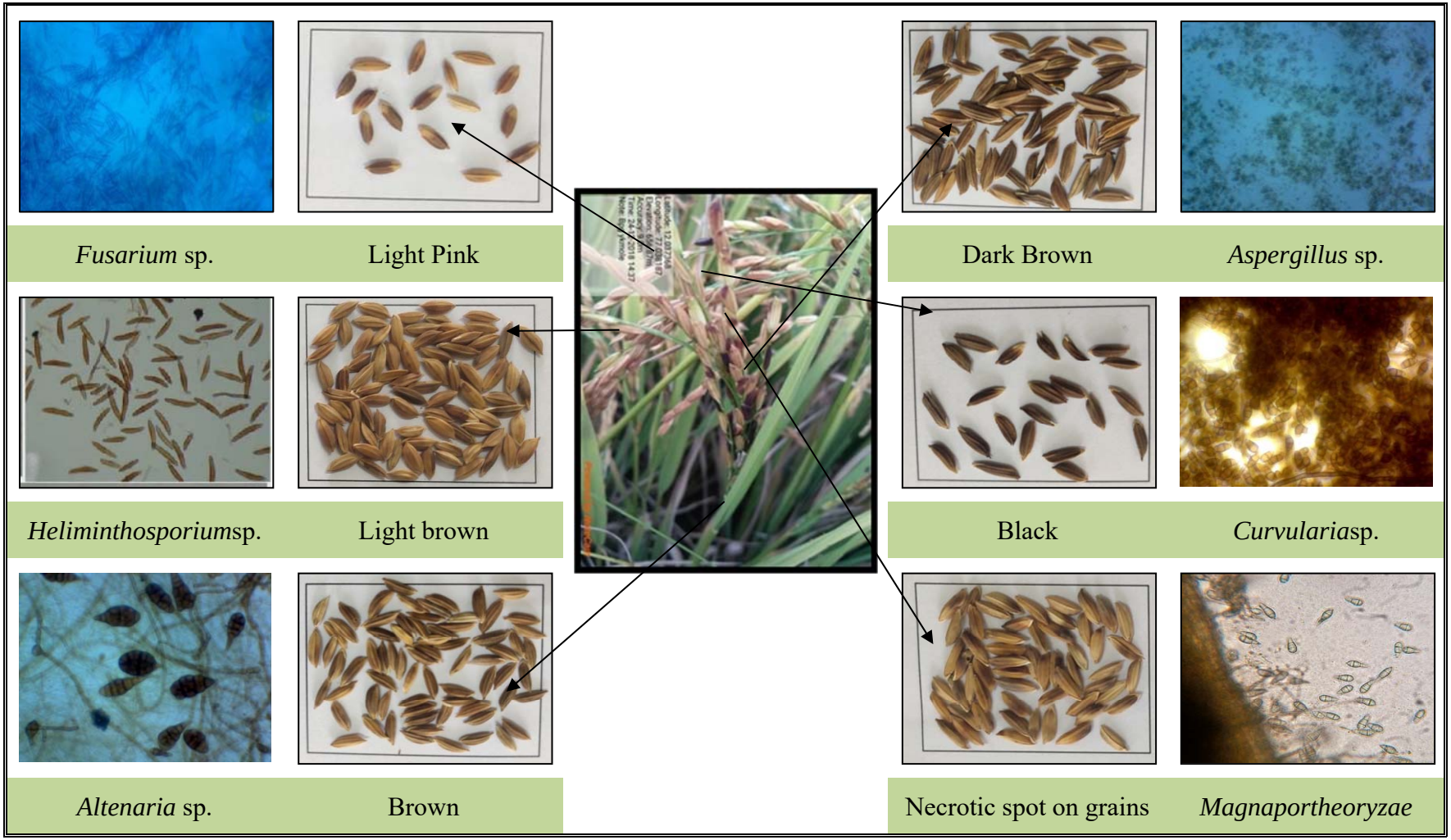


Plate 4. Fungal mycoflora colonized with discolourd rice grain samples (Genotype: BPT-5204)

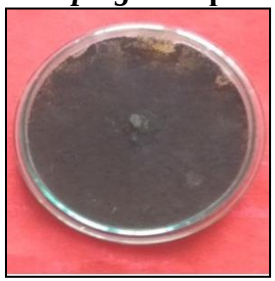
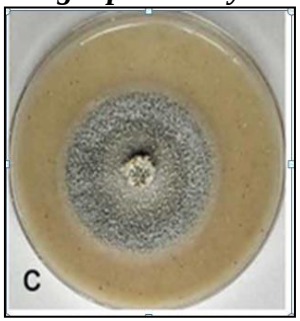
Mycoflora	Morphological character		Cultural character
***Trichoderma* sp.** 	Conidiophores	Appears long and frequently branched	20.36 mm of radial growth was observed after 48 hours. 1-2 concentric rings with green coloured conidia produced at centre and denser then move towards the margins. Conidia green in colour observed outer side of the plate and lower side appears dark greenish colour.
	Conidia	Globose to ellipsoidal in shape	
***Aspergillus* sp.** 	Conidiophore	Unbranched, aseptate, it developed from a thick specialized thick-walled cell and each conidiophore at its tip's forms enlarged swollen vesicle.	14.42 mm of radial growth was observed after 48 hours, outer side of the plate appears yellowish cream and lower side of the plate appears cream in colour
	Conidia	Brown or black, and yellow green in colour	
Magnaporthe oryzae 	Hyphae	Branched and septate.	Colour varied from grayish black to dark jet black colour, smooth to irregular margin, medium to good growth of the pathogen
	Conidiophoress	Emerging directly from the plant tissue bearing up to 20 conidia.	
	Conidia	Pyriform to obclavate, narrowed toward tip, rounded at the base, 2-septate, hyaline to pale brown, with a distinct basal hilum,	

Table 4.7. Seed mycoflora associated with discoloured grain samples of rice genotypes in blotter paper method

Sl. No.	Genoypes	Percent distribution of associated mycoflora								Total (%)	Germination (%)
		A	B	C	D	E	F	G	H		
1	IR-64	13	8	9	5	-	-	-	-	35	71
2	BR-2655	12	6	5	9	-	-	-	-	32	75
3	Jyoti	19	18	-	11	8	9	7	-	72	43
4	Super Aman	21	16	10	13	8	-	-	-	68	51
5	Jayashree	26	16	9	8	-	-	-	-	59	53
6	Jayakrishana	29	10	6	11	13	8	-	-	77	46
7	Gangavathi Sona	17	19	10	11	-	-	-	-	54	51
8	Jaya	14	7	-	8	-	-	-	-	29	81
9	Thanu	19	5	-	-	7	-	-	-	31	76
10	MTU 1001	9	8	-	-	3	3	-	-	29	79
11	MTU-1010	10	9	-	-	-	4	-	-	30	74
12	KRH-4	19	7	-	-	-	-	-	-	36	71
13	KMP-105	16	12	-	-	-	-	-	-	37	69
14	Abhilash	19	15	-	-	-	7	-	-	41	68
15	Hemavati	20	9	5	6	-	8	-	-	48	56
16	BPT-5204	12	17	5	13	11	-	7	13	78	39
17	RNR-15048	13	25	-	15	9	-	5	-	67	49
18	Nellur Sona	12	21	-	9	16	-	3	-	68	52
19	Kaveri Sona	15	18	-	7	6	-	-	-	51	54
20	Intan	13	6	-	5	-	16	-	-	40	73
21	Kajejaya	18	6	9	8	-	10	-	-	51	48
22	Rasi	10	9	-	-	-	-	-	-	27	85

A- *Helminthosporium* sp., B –*Curvularia* sp., C- *Alternaria* sp., D- *Aspergillus* sp., E -*Fusarium* sp., F- *Cladosporium* sp., G- P*homa* sp., H –*Magnaporthe oryzae* - Not observed

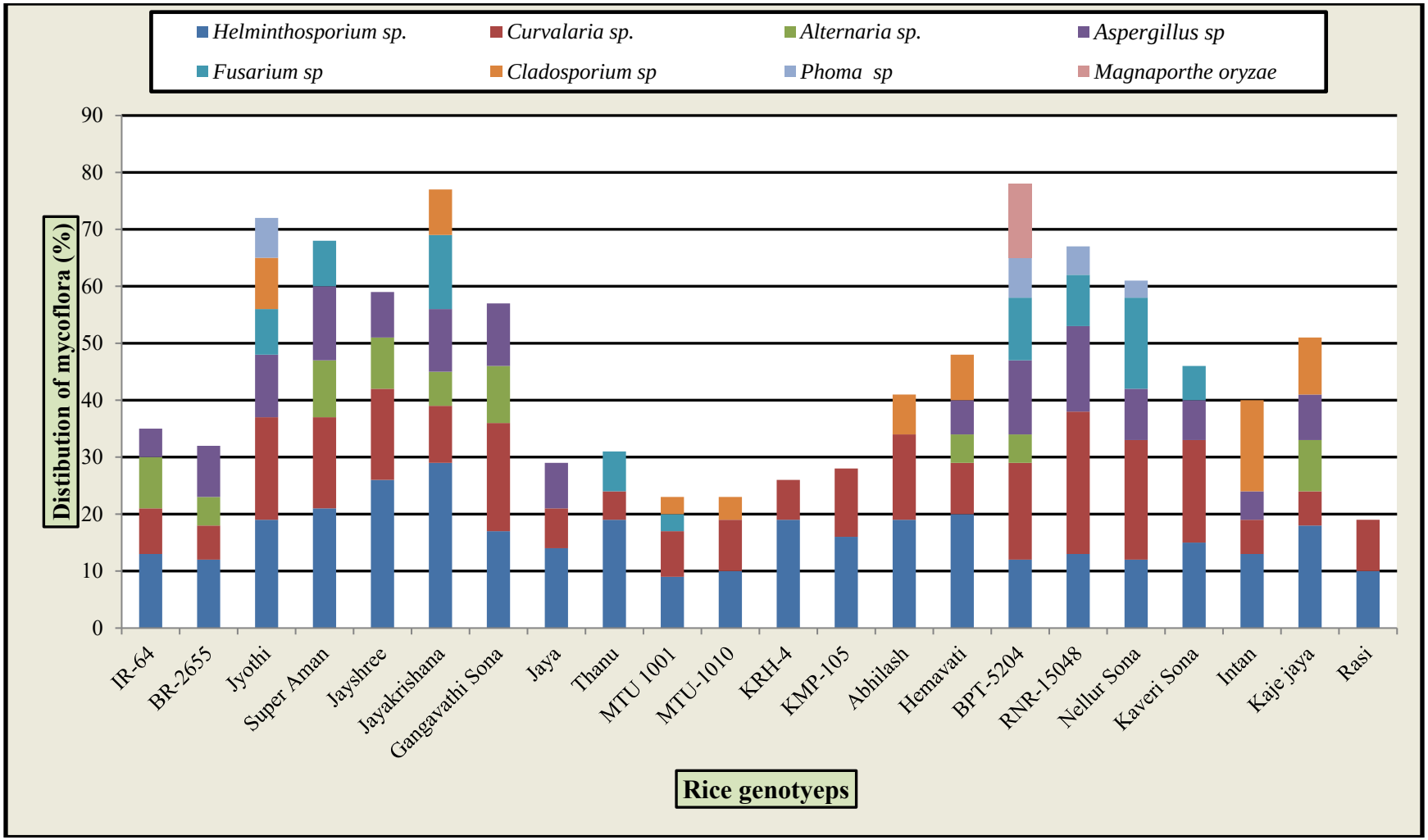


Fig. 4.5. Distribution of the fungal mycoflora (%) associated with discoloured grain samples of rice genotypes under blotter paper method

Alternaria sp., *Aspergillus* sp., *Fusarium* sp., *Cladosporium* sp., *Phoma sp*. and *Magnaporthe oryzae* were found colonized with the 22 grain samples (Table 4.8, Fig. 4.5). The highest diversity of mycoflora was noticed in variety BPT-5204 followed in Jyothi and Jayakrishna, Aman, MTU-1001, RNR-15048, Nellur Sona, Kaveri Sona,IR-64, BR-2655, Jayashree, Gangavati Sona, MTU-1010, KRH-4, Intan, Kaje Jaya and the least was in varieties Jaya, Thanu, KMP-105, Abhilasha and Rasi(Fig.4.6). The highest per cent distribution (78 %) of fungal mycoflora and maximun number of fungal pathogens associated (7) in BPT 5204. This is mainly because of this variety contains higher total sugar level (28, 82 mg/g, healthy and 34.82 mg/g, diseased grains) and lower phenol content (39.74 mg/g, healthy and 44.86 mg/g, diseased grains) leads to more susceptible to grain discolouration. Whereas, least per cent distribution of fungal mycoflora and lesser diversity of fungal pathogens were noticed in Rasi mainly because of higher content of phenol (55.76 mg /g, healthy and 64.98 mg/g, diseased grains) beside it was a short duration variety.

The present research findings are in agreement with the findings of Sharma *et al.* (1987), Ahmed *et al.* (1989), Agrawal *et al.* (1989), Mishra and Vir (1991), Ali *et al.* (1996), Pandey *et al.* (2000), Prakash and Rao(2001), Negi and Das(2003), Reddy *et al.* (2004), Chauhan *et al*.(2005), Samira *et al.*(2005) and Haque*et al.*(2007).

Nine fungal species *viz*., *Cuvurlaria* spp. (13.4%), *Alternaria padwickii* (12.0%), *Bipolaris oryzae* (4.9%), *Sarocladium oryzae* (1.9%), *Fusarium graminearum* (1.5%), *Tilletia barclayana* (0.16%), *Phoma sorghina* (0.1%), *Cephalosporium oryzae* (0.34%) and *Ustilaginoidea virens* (0.05%) reported by Van Du *et al.* (2001) from the 60 discoloured grains samples of 12 cultivars by blotter paper method.. The result was corroborating with the present findings. Mandhara *et al*. (2008) detected seven associated mycoflora, of which fivewere pathogenic to paddy. They were *Fusarium moniliforme, Fusarium oxysporium, Curvularia lunata, Drechslera oryzae, and Alternaria padiwickii*. Four fungal species namely *Helminthosporium* sp. *Fusarium moniliforme, Curvularia* sp.and *Alternaria* sp. from different test varieties under blotter paper method was reported by Butt *et al*., (2011). Seed borne pathogens *viz*. *Bipolaris oryzae, Curvularia lunata, Rhizopus stolonifer, Aspergillus* sp., *Phoma* sp*., Fusarium moniliforme,*

Table 4.8. Seed pathogens associated with discoloured grain samples of different rice genotypes isolated using blotter paper method

Sl. No.	Name of the variety	Type of species								No of mycofloral species found
		Helminthosporium sp.	*Curvularia* sp.	*Alternaria* sp.	*Aspergillus* sp.	*Fusarium* sp.	*Cladosporium* sp.	*Phoma* sp.	*Magnaporthe oryzae*	
1	IR-64	+	+	+	+	-	-	-	-	4
2	BR-2655	+	+	+	+	-	-	-	-	4
3	Jyoti	+	+	-	+	+	+	+	-	6
4	Super Aman	+	+	+	+	+	-	-	-	5
5	Jayashree	+	+	+	-	-	-	-	-	4
6	Jayakrishana	+	+	+	+	+	+	-	-	6
7	Gangavathi Sona	+	+	-	+	-	-	-	-	4
8	Jaya	+	+	-	+	-	-	-	-	3
9	Thanu	+	+	-	-	+	-	-	-	3
10	MTU 1001	+	+	-	+	+	+	-	-	5
11	MTU-1010	+	+	-	+	-	+	-	-	4
12	KRH-4	+	+	-	+	+	-	-	-	4
13	KMP-105	+	+	-	-	+	-	-	-	3
14	Abhilash	+	+	-	-	-	+	-	-	3
15	Hemavati	+	+	+	+	-	+	-	-	5
16	BPT-5204	+	+	+	+	+	-	+	+	7
17	RNR-15048	+	+	-	+	+	-	+	-	5
18	Nellur Sona	+	+	+	+	+	-	+	-	5
19	Kaveri Sona	+	+	+	+	+	-	-	-	5
20	Intan	+	+	-	+	-	+	-	-	4
21	Kajejaya	+	+	+	+	+	+	-	-	4
22	Rasi	+	+	-	-	+	-	-	-	3

+ (Present) - (Absent)

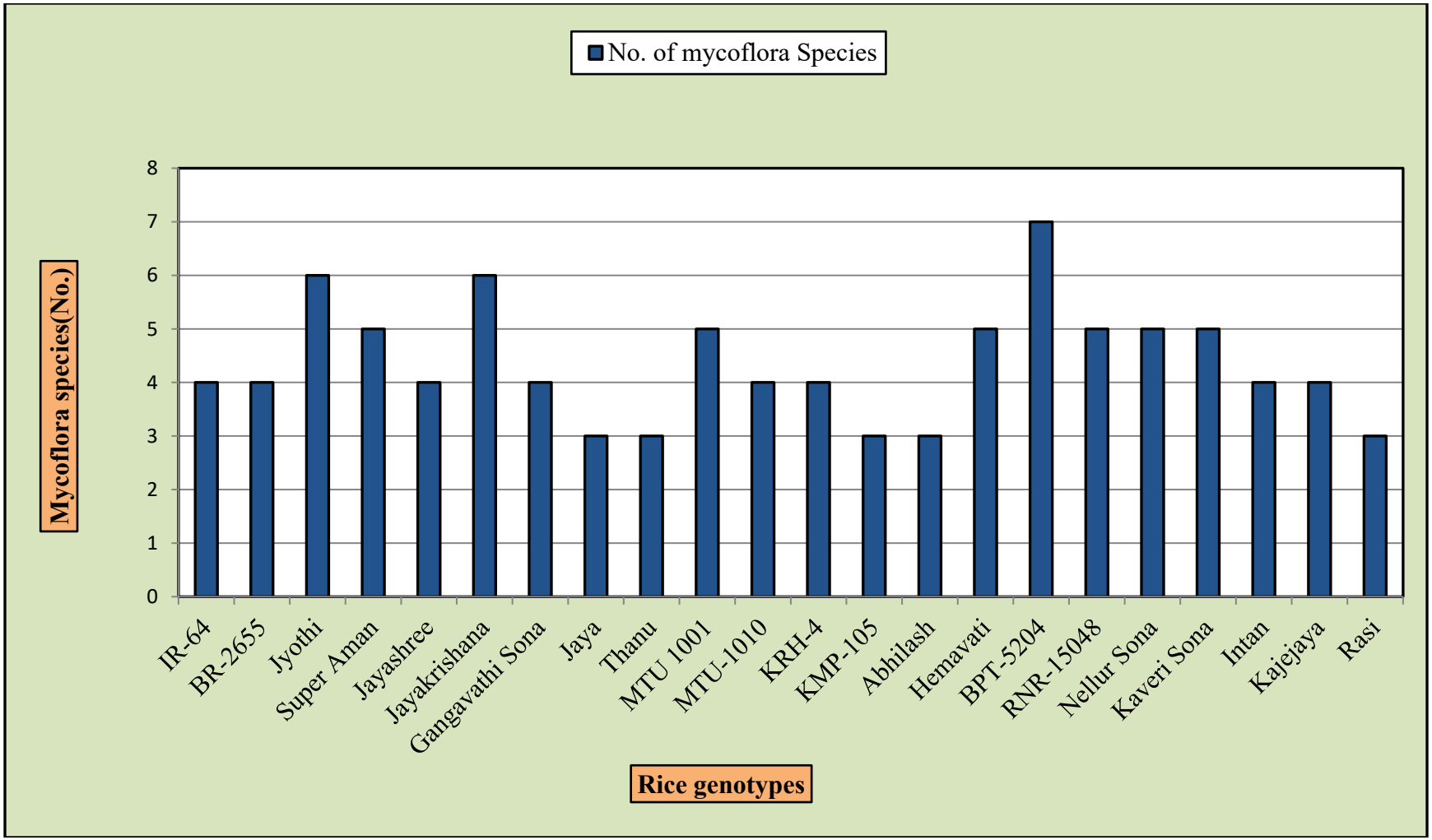


Fig. 4.6 Mycofloral species associated with discolourd grain samples of rice genotypes

		
Seed arrangement on blotter paper	Discoloured grains colonized by different pathogens after 4th day	Discoloured grains colonized by different pathogens after 7th day

Plate 5. Fungal mycoflora isolated from discoloured rice grains by Blotter paper method

Penicillium sp., *Chaetomium globosum, Alternaria tenuissima, Nigrospora oryzae, Tilletia barclyana* and *Xanthomonas oryzae* found associated with two local hybrid, 13 imported hybrid and two local varieties as check (Ora *et al.* 2011). Uma and Wesely (2013) reported five pathogenic fungi *viz. Alternaria padwickii, Aspergillus flavus, Penicillium citrinum, Aspergilus niger* and *Rhizopus oryzae* were detected from seeds of different varieties of rice. Rawtec (2013) reported pathogenic and saprophytic fungus *viz*. *Penicillium* sp., *Curvularia* sp., *Pyricularia* sp., *Sarocladium* sp., *Aspergillus* sp. *Fusarium* sp., *Phyllostieta* sp., *Diplodia* sp., and *Alternaria* sp. was done by standard blotter paper method.

4.4.2 Detection of seed pathogens by agar plate method

Discoloured rice grain samples of twenty-two rice genotypes were collected from three rice ecosystems. Pathogens from rice grain samples were subjected to agar plate method. Later, the pathogenic fungi were detected from each genotype. A total number of sevenmycoflora species namely *Curvularia* sp., *Helminthosporium sp.*, *Alternaria* sp., *Aspergillus sp*., *Fusarium* sp., *Trichoderma* sp. and *Rhizopus* sp.were found associated with the 22 grain samples.Further, the distribution of fungal mycoflora (%) from each genotypes were also studied andvaried from 16 to 79 per cent distribution of fungal pathogens was noticed with 22 genotypes of rice seed. Whereas, the highest percent distribution of fungal mycoflora was recorded in variety BPT-5204 (79%) followed by Jyothi (78%) and Jayakrishna (68%) while the least percent distribution of mycoflora was noticed in varieties Jaya (16%) followed by BR-2655 (17%) and Rasi (18%) (Table 4.9, Fig. 4.7). Whereas, the highest diversity of mycoflora was found in Jyothi(6) and BPT5204 (6) followed by Aman(5), Jayashree (5), Intan(5), Jayakrishna(4),Gangavati Sona(4), MTU -1010 (4), KM-105(4), RNR15048(4), Nellur Sona(4), Kaveri Sona (4), IR-64(3), Jaya(3), Thanu(3), MTU-1010(3), KRH-4(3), Kajejaya(3) and Rasi(3), and minimum was in varieties BR-2655(2), Abhilash(2) and Hemavati(2) (Table 4.10, Fig. 4.8, Plate 6). The highest per cent distribution and maximum diversity of fungal pathogens was noticed in BPT 5204 among isolated twenty two rice genotypes. It showed this variety has highly susceptible to fungal pathogen. This susceptibility is due to presence of lower phenol content (39.74 mg/g) and high total sugar level (28.82 mg/g). Other varieties like Jaya (16%), BR 2655 (17%) and Rasi (18 %) were showed lesser per

Table 4.9. Distribution of the mycoflora (%) associated with discoloured rice grain samlpes of rice genotypes under agar plate method

Sl. No.	Name of the genotype	Distribution of mycoflora (%)							Total (%)
		A	B	C	D	E	F	G	
1	IR-64	3	6	-	-	11	-	-	20
2	BR-2655	-	-	-	8	9	-	-	17
3	Jyothi	11	10	16	14	23	-	4	78
4	Super Aman	13	11	8	15	19	-	-	66
5	Jayshree	9	9	-	19	22	5	-	64
6	Jayakrishana	15	6	18	-	29	-	-	68
7	Gangavathi Sona	8	9	17	-	16	-	-	50
8	Jaya	-	7	-	5	4	-	-	16
9	Thanu	-	8	-	8	5	-	-	21
10	MTU 1001	8	-	8	-	4	-	-	20
11	MTU-1010	9	5	8	-	8	-	-	30
12	KRH-4	5	6	-	8	9	-	-	28
13	KMP-105	7	6	-	4	15	-	-	32
14	Abhilash	-	8	-	-	13	-	7	28
15	Hemavati	-	-	9	-	17	6	-	32
16	BPT-5204	11	7	17	12	27	5	-	79
17	RNR-15048	8	16	-	10	17	-	-	51
18	Nellur Sona	6	11	19	-	16	-	-	52
19	Kaveri Sona	9	9	16	-	18	-	-	52
20	Intan	6	4	6	-	7	5	-	28
21	Kaje Jaya	-	5	-	7	8	-	-	20
22	Rasi	4	-	5	-	9	-	-	18

A- *Fusarium* sp. B - *Aspergillus* sp. C - *Curvalaria*sp. D -*Alternaria* sp. E- *Helminthosporium* sp. F - *Trichoderma* sp. G –*Rhizopus* sp. * - Not observed

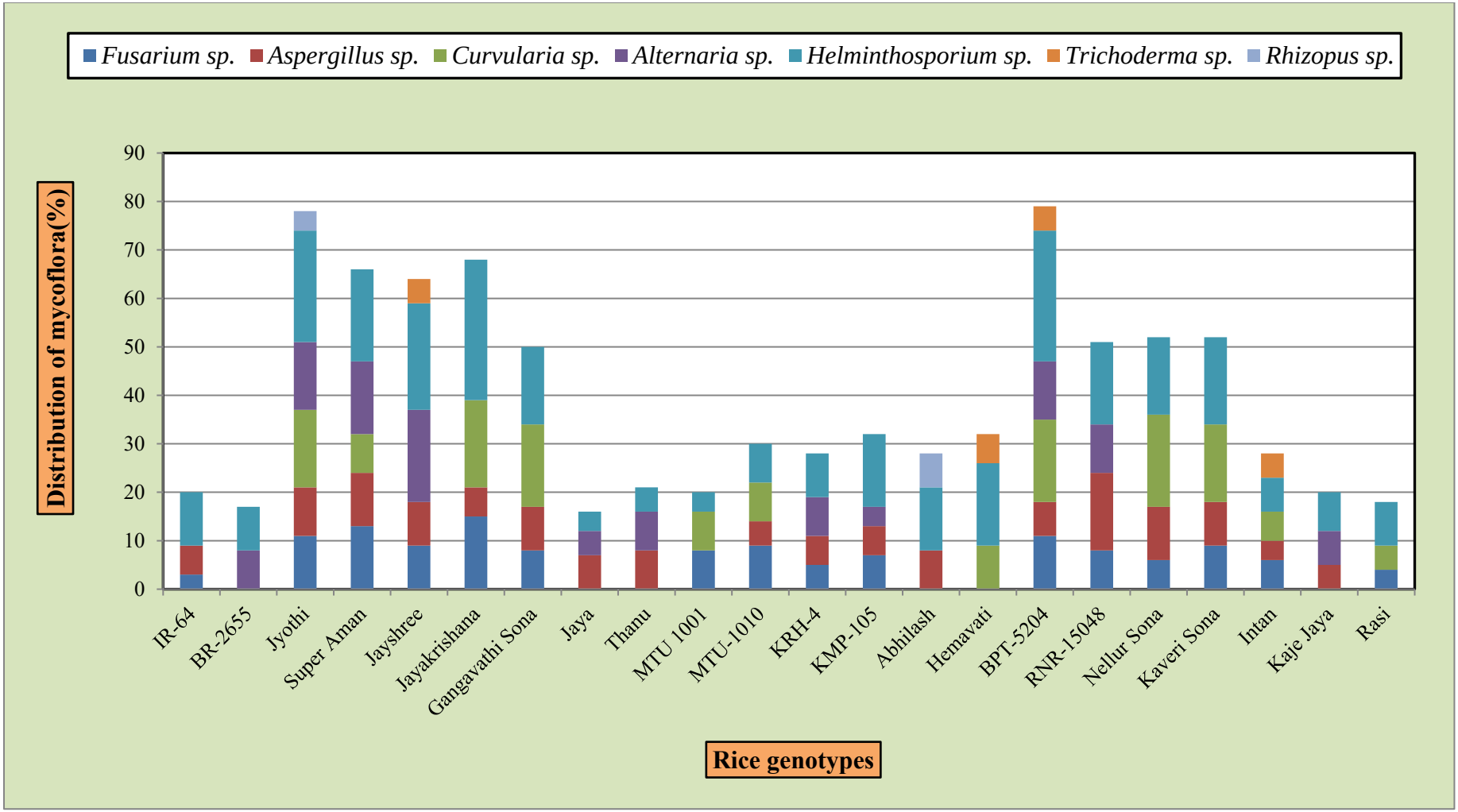


Fig.4.7. Distribution of the fungal pathogens (%) associated with discoloured rice grain samples of different rice genotypes

Table 4.10. Fungal mycoflora associated with discoloured grains samples of different rice genotypes isolated under agar plate method

Sl. No.	Name of genotype	Type of species							Mycoflora species (No.)
		Fusarium sp.	*Aspergillus* sp.	*Curvularia* sp.	*Alternaria* sp.	*Helminthosporium* sp.	*Trichoderma* sp.	Rhizopus sp.	
1	IR-64	+	+	-	-	+	-	-	3
2	BR-2655	-	-	-	+	+	-	-	2
3	Jyoti	+	+	+	+	+	-	+	6
4	Super Aman	+	+	+	+	+	-	-	5
5	Jayashree	+	+	-	+	+	+	-	5
6	Jayakrishana	+	+	+	-	+	-	-	4
7	Gangavati Sona	+	+	+	-	+	-	-	4
8	Jaya	-	+	-	+	+	-	-	3
9	Thanu	-	+	-	+	+	-	-	3
10	MTU 1001	+	-	+	-	+	-	-	3
11	MTU-1010	+	+	+	-	+	-	-	4
12	KRH-4	+	+	-	+	-	-	-	3
13	KMP-105	+	+	-	+	+	-	-	4
14	Abhilash	-	+	-	-	+	-	-	2
15	Hemavati	-	-	+	-	+	-	-	2
16	BPT 5204	+	+	+	+	+	+-	-	6
17	RNR-15048	+	+	-	+	+	-	-	4
18	Nellur Sona	+	+	+	-	+	-	-	4
19	Kaveri Sona	+	+	+	-	+	-	-	4
20	Intan	+	+	+	-	+	+	-	5
21	Kaje Jaya	-	+	-	+	+	-	-	3
22	Rasi	+	-	+	-	+	-	-	3

+ (Present) - (Absent)

cent distribution of fungal pathogen and least diversity of mycoflora. These varieties are having higher range of phenol content varied from 51.77 to 64.10 per cent and lower sugar content ranged from 22.87 to 28.47 mg/g leads to development of host resistance.

Our present research findings are in accordance with the many other research workers *viz*., Sharma and Chaudhary, (1986); Sharma *et al.*(1987); Misra and Vir, (1988); Prakash *et al*. (2001); Chauhan *et al*., (2005); Samira *et al.,* (2005); Tripathi and Jain (2005); Gopalakrishnan *et al.,* (2010); Uma and Wesely, (2013) and Sabina *et al*., (2018). Similar findings were also declared by Babo and Lokesh (1996) who recorded 24 fungal species, out of which*, F. moniliforme*, *Drechslera sp.*, *Aspergillus sp., Chaetomium sp., globosum sp., Rhizopus sp.,* and *Verticillium sp.,* were frequently associated with rice seeds samples procured from different agro climatic regions of Karnataka.

4.4.3 Detection of seed pathogens colonized with discolourd rice grains by paper towel method

Discoloured rice grain samples of 22 genotypes were tested by paper towel method. Total seven pathogenic mycoflora *viz.*, *Fusarium* sp., *Aspergillus* sp., *Curvularia* sp., *Alternaria* sp., *Helminthosporium sp., Trichoderma* sp. and *Rhizopus* sp. (Table 4.11, Fig.4.9) were isolated. Further, the per cent distributions of pathogenic mycoflora was assessed in each rice genotype and varied from 14 to 65 per cent. The highest percent pathogenic mycoflora were recorded with the variety Jyothi (65%) followed by BPT 5204 (64%), Jayakrishna (63%) and Aman (60%). Whereas, the genotype Jaya showed least per cent of distribution (14 %) followed by Kaje Jaya (15%), Rasi (16%) and BR-2655 (16%).

In paper towel method, the highest diversity of mycoflora were found in Jyoti with six mycofloral species (*Fusarium* sp*., Aspergillus* sp., *Curvularia sp*., *Alternaria* sp., *Helminthosporium* sp. and *Rhizopus* sp.), whereas, *Aspergillus* sp. and *Helminthosporium* sp.were only observed in BR-2655, *Curvularia* sp. and *Helminthosporium* sp.observed in Jaya, whereas *Alternaria* sp.and *Helminthosporium* sp. were noticed in KajeJaya and Rasi, respectively **(**Table 4.12, Plate 8, and Fig.4.10). The highest per cent distribution (65%) and maximum diversity of fungal mycoflora (6) was noticed in Jyothi mainly

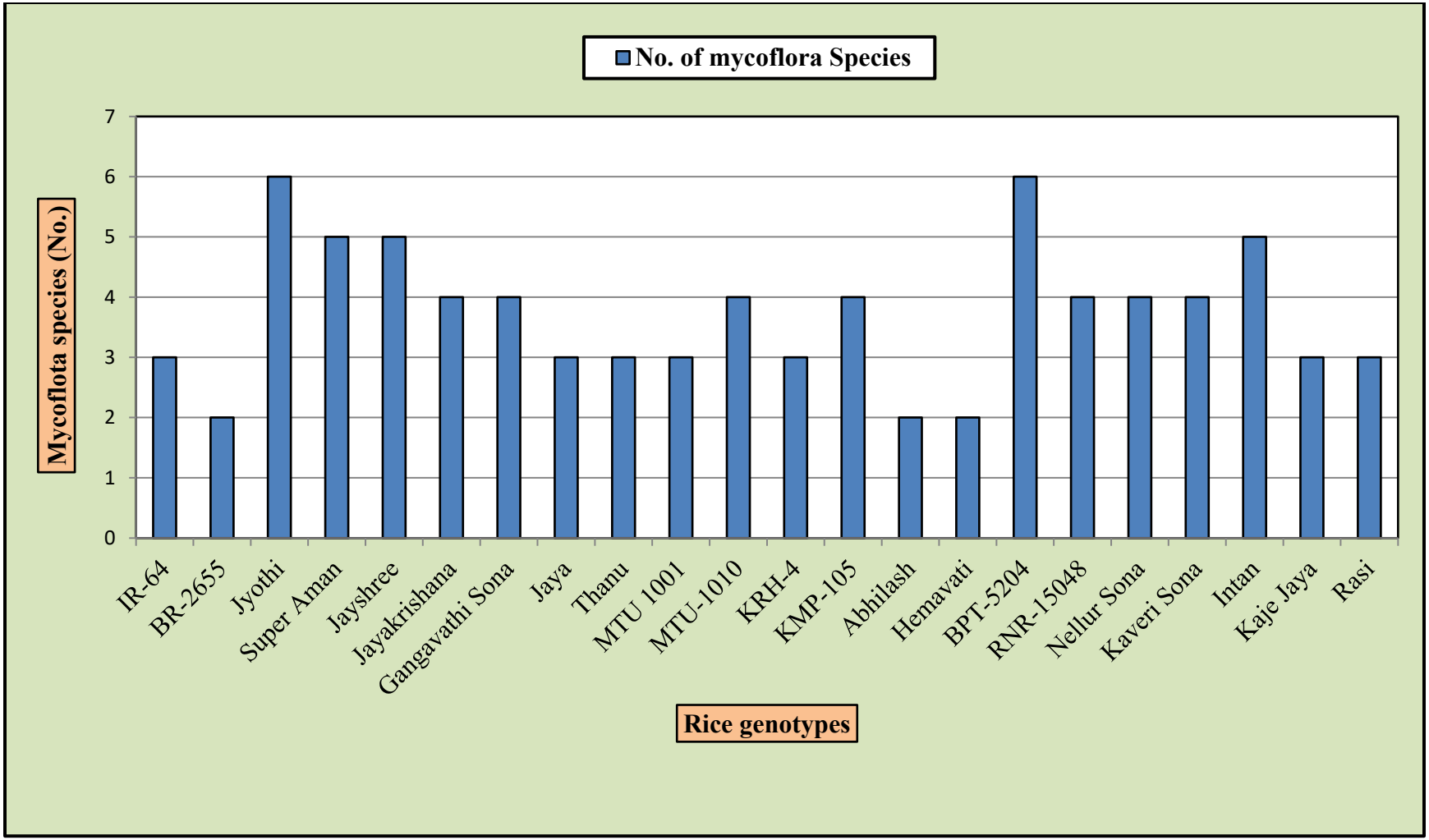


Fig. 4.8. Number of mycoflora species associated discoloured rice grain samples of rice genotypes under agar plate method

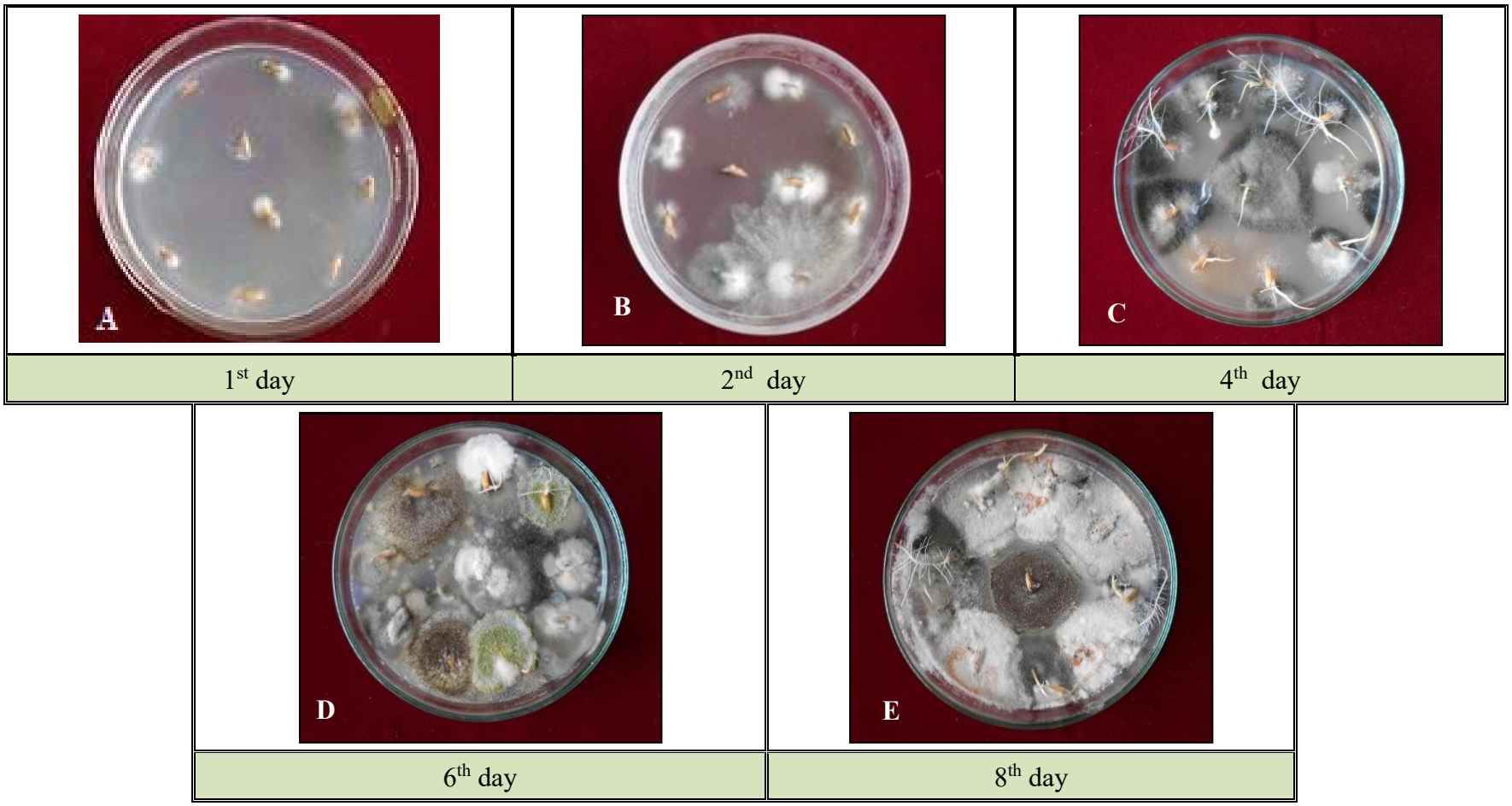


Plate 6. Seed borne fungal pathogens associated with discoloured rice grains cv. BPT 5204 (Agar plate method)

Table 4.11. Distribution of mycoflora (%) associated with discoloured grain samples of different rice genotypes isolated under paper towel method

Sl. No.	Name of the variety	Distribution of mycoflora (%)							Total (%)	Seed Germination (%)
		A	B	C	D	E	F	G		
1	IR-64	-	5	-	9	17	-	-	31	66
2	BR-2655	-	3	-	-	12	-	-	15	77
3	Jyothi	9	9	18	8	16	-	5	65	53
4	Super Aman	-	19	11	9	21	-	-	60	51
5	Jayashree	-	8	-	15	18	7	-	48	65
6	Jayakrishana	16	17	12	9	9	-	-	63	51
7	Gangavati Sona	-	8	7	5	9	-	-	29	71
8	Jaya	-	-	8	-	6	-	-	14	80
9	Thanu	-	-	12	8	9	-	-	29	63
10	MTU- 1001	-	8	7	-	8	-	-	23	65
11	MTU-1010	-	9	4	9	12	-	-	34	69
12	KRH-4	-	-	-	8	16	-	-	24	64
13	KMP-105	-	5	-	9	8	-	-	22	67
14	Abhilash	-	7	8	-	15	-	9	39	56
15	Hemavati	-	-	6	-	8	8	-	22	71
16	BPT-5204	12	-	21	10	21	-	-	64	61
17	RNR-15048	14	-	17	-	-	-	-	31	76
18	Nellur Sona	-	8	-	8	9	-	-	25	78
19	Kaveri Sona	-	7	-	9	9	-	-	25	79
20	Intan	-	6	-	-	9	8	-	23	80
21	Kaje Jaya	-	-	-	9	7	-	-	16	81
22	Rasi	-	-	-	7	9	-	-	16	80

A – *Fusarium* sp. *B* - *Aspergillus* sp., C – *Curvularia* sp., D – *Alternaria* sp., E – *Helminthosporium* sp., F – *Trichoderma* sp., G –Rhizopus sp., *- Not observed

Table 4.12. Discoloured rice grain samples of different rice genotypes were colonized by various fungal mycoflora using paper towel method

Sl. No.	Name of genotypes	Fungal Mycoflora							Mycofloral species (No.)
		Fusarium sp.	*Aspergillus* sp.	*Curvularia* sp.	*Alternaria* sp.	*Helminthosporium* sp.	*Trichoderma* sp.	*Rhizopus* sp.	
1	IR-64	-	+	-	+	+	-	-	3
2	BR-2655	-	+	-	-	+	-	-	2
3	Jyoti	+	+	+	+	+	-	+	6
4	Super Aman	-	+	+	+	+	-	-	4
5	Jayashree	-	+	-	+	+	-	-	3
6	Jayakrishana	+	+	+	+	+	-	-	5
7	Gangavati Sona	-	+	+	+	+	-	-	4
8	Jaya	-	-	+	-	+	-	-	2
9	Thanu	-	-	+	+	+	-	-	3
10	MTU 1001	-	+	+	-	+	-	-	3
11	MTU-1010	-	+	+	+	+	-	-	4
12	KRH-4	-	-	-	+	+	-	-	2
13	KMP-105	-	+	-	+	+	-	-	3
14	Abhilash	-	+	+	-	+	-	+	4
15	Hemavati	-	-	+	-	+	+	-	3
16	BPT5204	+	-	+	+	+	-	-	5
17	RNR-15048	+	-+	+	-	-	-	-	3
18	Nellur Sona	-	+	-	+	+	-	-	3
19	Kaveri Sona	-	+	-	+	+	-	-	3
20	Intan	-	+	-	-	+	+	-	3
21	Kaje Jaya	-	-	-	+	+	-	-	2
22	Rasi	-	-	-	+	+	-	-	2

+ (Present) - (Absent)

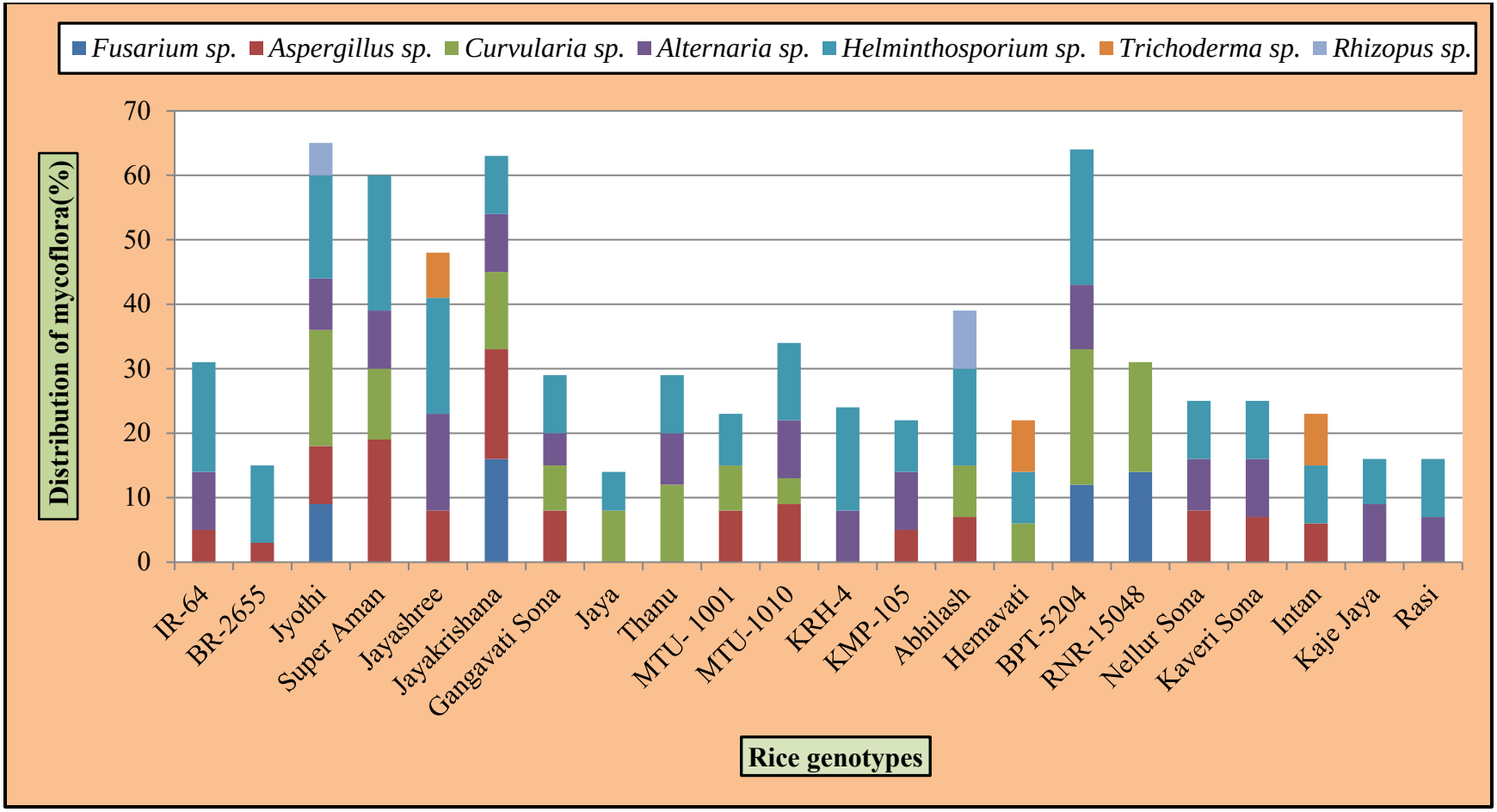


Fig.4.9. Seed mycoflora associated with discloured grain samples of different rice genotyeps

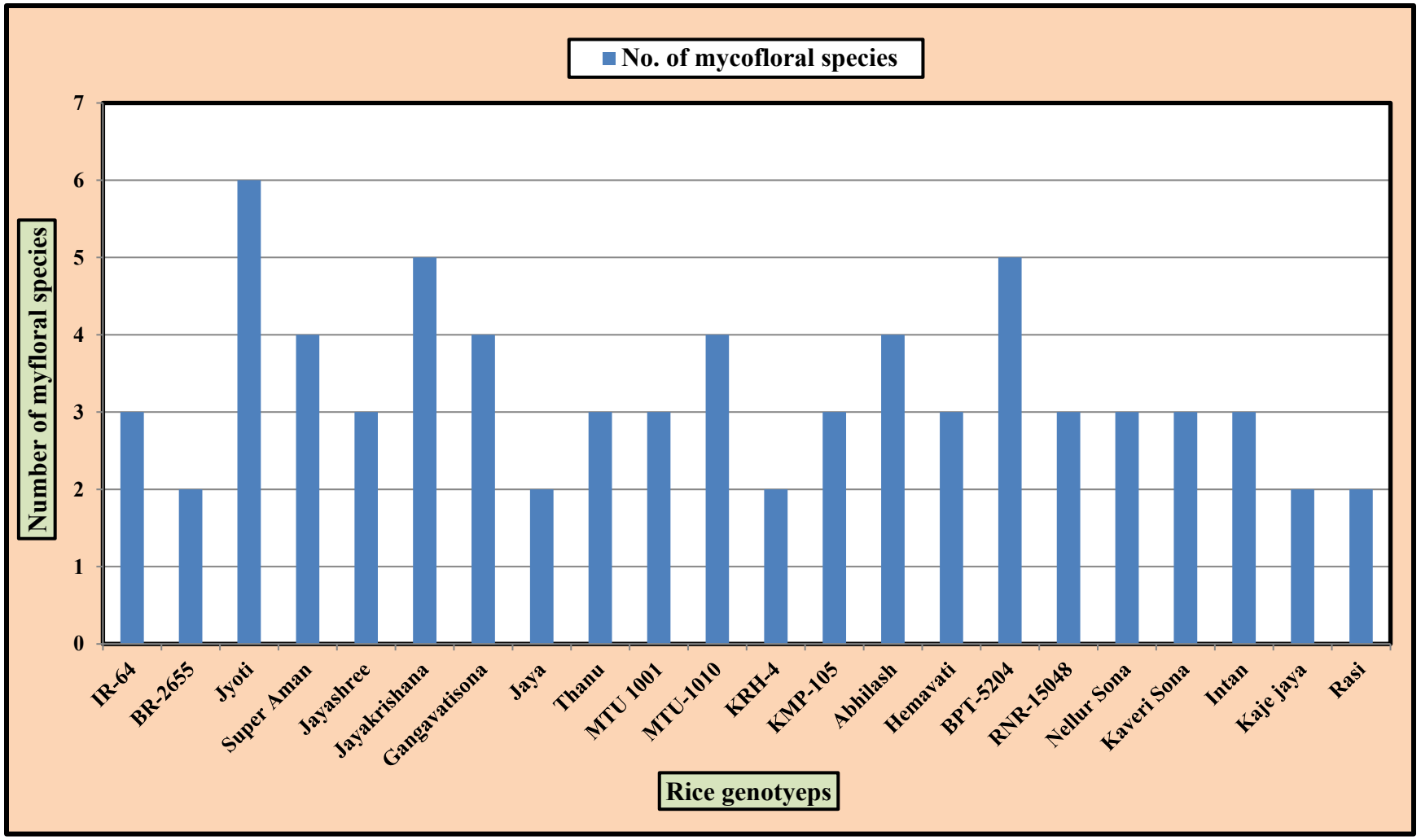


Fig.4.10. Number of mycoflora species associated discolored grain samples of rice genotypes assessed by paper towel method

	
Discoloured seeds placed on Paper towel	**Germination and association of mycoflora after 10^{th} day**
	
Seed infection	**Seedling infection**

Plate 7. Seed mycoflora associated with dicoloured rice grain sample of rice genotype (BPT 5204)

because it contained lower phenol content (48.65 mg/ 100 g) and higher sugar (27.82 mg/g). Whereas least per cent distribution of fungal mycoflora was in Kaje Jaya (15%) and Rasi16%). It might be due to higher phenol content (44.12% and 55.76%) respectively in both varieties. The present research findings are in acceptance with Ora *et al.* (2011) who identified seed mycoflora*viz., Bipolaris oryzae, Curvularia lunata, Xanthomonas oryzae* p.*v. oryzae Rhizopus stolonifer, Fusarium moniliforme, Phoma* sp*., Penicillium* sp., *Alternaria tenuissima, Aspergillus* sp., *Nigrospora oryzae, Chaetomium globosum* and *Tilletia barclyana* associated with various rice hybrids (Imported hybrid were 13, local rice hybrids were 2 and local two rice varieties as check). The pathogens *viz.*, *Bipolaris oryzae, Xanthomonas* spp*., Aspergillus* sp., *Rhizopus stolonifer* and *Fusarium moniliforme* were predominant all the hybrid rice varieties in blotter method, paper towel method and agar plate method.

4.5 Screening of genotypes for reaction to grain discolouration of rice

The successful usage of chemicals for the management of rice grain discolouration disease depends onvarious factors including economics. Besides, the frequent use of chemicals may lead to inducement of resistant mutants of target fungus which is more dangerous as well as difficult to manage. The identified genotypes like resistant and moderately resistant may be recommended for cultivation in endemic areas of this disease and also this source could be utilized for crop improvement programme. Therefore, totally 38 rice genotypes were obtained from Zonal agricultural research station, V. C. Farm, Mandya. Further, these genotypes were screened in farmers' field in Y. K. Mole village in Yalandur taluk of Chamarajangara district against the grain discolouration under natural incidence conditions during *Kharif* 2017 and 2018. The observations were recorded and presented in Table 4.13, Fig.4.12, Fig.4.13 and Fig. 4.14. The data revealed that, during both the years (2017 and 2018) the significant differences and varied levels of incidence of grain discolouration was documented in all the tested genotypes.

Totally thirty-eight rice genotypes were assesed during the *Kharif* 2017. The grain discolouration incidence was present in all genotypes and ranged from 4.50% to 48.00%.

The maximum per cent incidence (48.00 %) was observed in Jyothi, which was significantly higher among any other genotypes followed by Mandya Vijaya (46.50%) and BPT5204 (42.14%). The lowest grain discolouration was noticed in BR- 2655 (4.50%) followed by Ratnachudi (4.80 %), KMP-153 (5.00 %) and KCP-1 (5.00 %) whereas check variety JGL-1758 has showed 31.80% percent grain discolouration. Out of 38 genotypes, 7 genotypes *viz.*, Gangavathi Sona (34.00%), KMP201 (35.00%), KMP175 (36.00%), Basumati - 270 (41.50%), BPT5204 (42.14 %), Mandya Vijaya (46.50 %) and Jyoti (48.00%) were showed higher per cent of grain discolouration and thirty one genotypes were showed lower per cent of discolouration over check variety JGL1758 (31.80 %) (Table 4.13 and Fig. 4.12). The earlier research findings declared that the JGL 1758 was highly susceptible check for rice grain discolouration. Henceforth this variety has been kept as a check in our screening work. In our research finding, among 38 genotypes tested *viz.*, Gangavathi Sona (34 %), KMP 201 (35 %), KMP 175 (35 %), Basumati 270 (41.50%), BPT 5204 (42.14%), Mandya Vijaya (46.50%) and Jyothi (48 %) have showed higher incidence of diseases over check variety (JGL-1798).

During *Kharif* 2018, the incidence of grain discolouration was prevalent in all tested genotypes and it ranged from 4.85% to 49.00%. The highest incidence of rice grain discolouration was recorded in MandyaVijaya (49.00 %) followed by Jyothi (45.00 %) and BPT5204 (39.40%). Whereas, lowest percent incidence recorded in KCP -1 (4.85%) followed by Ratnachudi (4.88%) and Jaya (4.88%), respectively. The check variety JGL1758 has showed (38.40 %) discolouration. Among 38 genotypes, 4 genotypes *viz*., Basumati 270 (39.00%), BPT 5204 (39.40%), Jyothi (45.00%) and Mandya Vijaya (49.00%) have showed higher per cent of grain discolouration and the remaining 34 genotypes showed lower per cent of grain discolouration over check variety (JGL 1758) (Table 4.13 and Fig.4.13).

The average of *Kharif* 2017 and 2018 result data revealed that (Table 4.13 and Fig. 4.24) the mean per cent grain discolouration in all genotypes ranged from 4.75 to 47.75 %, whereas the highest incidence of grain discolouration noticed in Mandya Vijaya (47.75 %) and least incidence in Jaya (4.75 %). Whereas, JGL1758 a check variety showed 31.50 % grain discolouration. Our research results are in acceptance with Divya

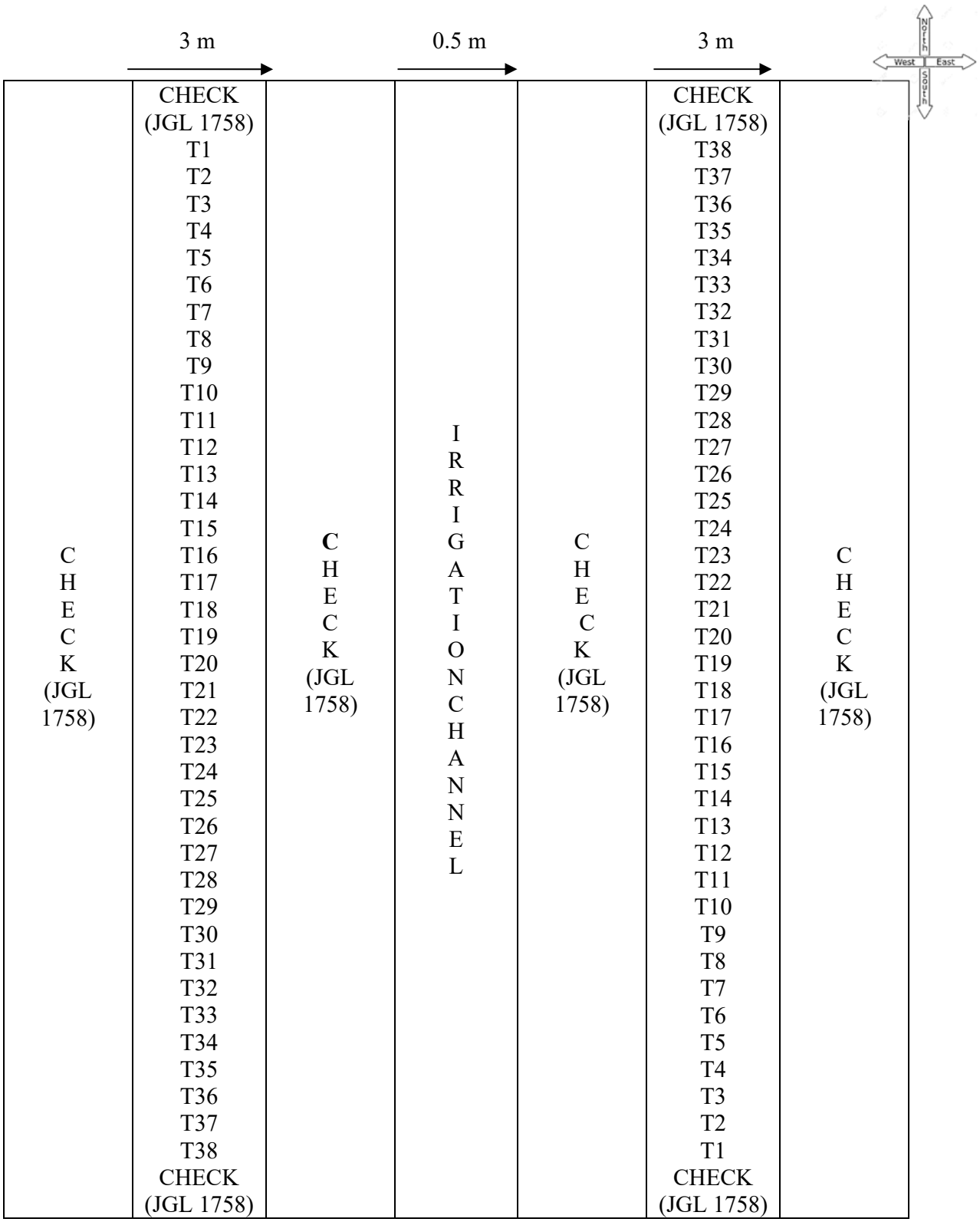


Fig.4.11. Layout for field evaluation of rice genotypes for resistance to grain discolouration

	
Preparation of nursery	**Nursery at 22 days**
	
Land preparation for planting	**Planting stage**
	
Panicle emergence stage	**Maturity stage**

Plate 8. Field view of research plot for screening different rice genotypes

Table 4.13. Screening of rice genotypes against rice grain discoloration during *Kharif* 2017 and 2018 in Yalandur taluk of Chamarajanagara district

Genotyeps	Per cent discoloration		
	Kharif 2017	*Kharif* 2018	Pooled
Rasi	9.08 (17.50)	5.08 (12.94)	7.08 (15.39)
KMP-153	5.00 (12.92)	8.00 (16.31)	6.50 (14.72)
IR-64	21.00 (27.25)	19.50 (26.19)	20.25 (26.74)
Mandya Sona- 2	16.00 (23.56)	18.00 (25.07)	17.00 (24.32)
Raksha	14.50 (22.25)	11.50 (19.77)	13.00 (21.09)
KMP- 201	35.00 (36.26)	29.00 (32.57)	32.00 (34.44)
KMP- 128	16.80 (24.16)	12.60 (20.74)	14.70 (22.50)
KMP- 175	36.00 (36.87)	31.60 (34.18)	33.80 (35.55)
BR- 2655	4.50 (12.18)	5.00 (12.86)	4.75 (12.52)
Jaya X ASD	8.00 (16.31)	7.00 (15.26)	7.50 (15.84)
MTU -1010	21.66 (27.73)	18.00 (25.07)	19.83 (26.44)
BPT-5204	42.14 (40.47)	39.40 (38.88)	40.77 (39.67)
Jyothi	48.00 (43.85)	45.00 (42.18)	46.50 (42.99)
Basumati -270	41.50 (40.10)	39.00 (38.64)	40.25 (39.37)
IR- 30864	19.00 (25.81)	23.00 (28.64)	21.00 (27.25)
Jyothi X BR-2655	18.00 (25.10)	24.00 (29.31)	21.00 (20.51)
CTH- 1	9.75 (18.16)	14.80 (22.58)	12.27 (28.82)
HR-12	24.53 (29.67)	22.00 (27.95)	23.26 (24.71)
MSN-100	16.00 (23.57)	19.00 (25.81)	17.50 (21.08)
KMP- 200	12.00 (20.20)	14.00 (21.92)	13.00 (30.63)
CTH -3	24.00 (29.33)	28.00 (31.93)	26.00 (29.36)
GVT -7	20.55 (26.93)	27.58 (31.66)	24.06 (23.54)
GVT-4	14.00 (21.92)	18.00 (25.07)	16.00 (36.33)
JGL-1798 (Check)	31.80 (34.32)	38.40 (38.29)	35.10 (27.22)
KRH-4	18.00 (25.07)	24.00 (29.31)	21.00 (31.07)
Mandya Sona -1	25.88 (30.56)	27.50 (31.61)	26.69 (12.65)
Jaya	4.80 (12.60)	4.88 (12.70)	4.84 (33.82)
Gangavathi Sona	34.00 (35.66)	27.00 (31.29)	31.00 (43.71)
Mandya Vijaya	46.50 (42.99)	49.00 (44.43)	47.75 (12.75)
KCP-1	5.00 (12.86)	4.85 (12.67)	4.92 (20.90)
MTU- 1001	9.00 (17.36)	17.50 (24.68)	12.75 (28.98)
Tellahamsa	19.00 (25.81)	28.00 (31.93)	23.50 (12.89)
Rajamudi	5.08 (13.01)	4.88 (12.70)	4.98 (12.89)
Thanu	30.00 (33.20)	35.50 (36.56)	32.75 (34.90)
Ratnachudi	4.80 (12.59)	4.90 (12.71)	4.85 (12.65)
RNR -15048	24.00 (29.31)	29.00 (32.57)	26.50 (30.95)
MSN -99	12.00 (20.20)	10.00 (18.35)	11.00 (19.30)
KMP -149	10.80 (19.15)	9.90 (18.25)	10.35 (18.71)
S. Em±	1.30	1.40	1.32
C.V.	7.32	7.61	7.22
C.D. @5%	3.77	4.02	3.78

*(Figures in parenthesis are arc sine transformed value)

(2015) who reported the variety NLR 34449 (40.68%) was showed highest grain discolouration, which was highly significant than any other genotypes. Whereas, MTU 1010 has recorded as lowest grain discolouration (14.78%) and it was on a par with BPT 1768 followed by MTU 1064 (15.93%) and NLR 3041 (19.05%). In remaining varieties, grain discolouration was between 19.61% (PAC 837) and 31.35% (MTU 2067).

Totally thirty-eight rice genotypes comprising short, medium and long duration were screened against rice grain discolouration during *Kharif* 2017 and 2018 in farmer's field at Y. K. Mole village in Yalandur taluk of Chamarajanagara district under natural conditions. The results revealed that, among 38 genotypes screened, none of the genotype was found immune or resistant. However, five genotypes were found moderately resistant viz., Jaya, BR-2655, Rajamudi, KCP-1 and Ratnachudi.These rice genotypes were showed moderately resistant reaction against grain discoloration due to presence of higher phenol content and which was ranged from in 75.09 to76.87 mg/g in discolouredgrains and higher sugar level ranged from 21.01 to 23.66 mg/g in healthy and23.09 to 25.79 mg/g in disease grain.Other 21 genotypes *viz.,* KMP-153, Rasi, IR-64, CTH-1,Mandya sona-2,MTU-1010, Raksha, KMP-128, IR-38064,Jaya X ASD MSN-100, KMP-200, GVT-7, GVT-4, KRH-4,MTU-1001, Tellahamsa,MSN-99,KMP-149, Jyothi X BR-2655 and HR-12 were moderately susceptible. Whereas, these genotypes (21) have showed lower phenol content in discoloured grains and it was ranged from61.87 to 64.98 mg/g and lower sugar level in discoloured grains ranged from 22.87 to 25.97mg /g and 12 genotypes were susceptible *viz.*BPT-5204*,* KMP-175, KMP-201,Jyoti,JGL-1798,Basumati -270, Mandy Sona-1, Gangavathi Sona, RNR-58048,Mandya Vijaya, CTH-3andThanu. The susceptible reaction in 12 genotype was mainly due to presence of lower phenol content and it varied from 44.86to 55.98mg/g in discoloured grains and higher sugar level (31.92 to 34.82 mg/g) and none of the tester genotypes showed highly susceptible reaction (Table 4.14, Plate 9).The present results are in acceptance with findings of Saifulla (1997), Bhimanagouda (2012), Divya (2015) and VarshaShekhara (2018).

The highest incidence of discolouration in rice grain genotypes was recorded in the month of November and December during *2017* and 2018; respectively. It might be

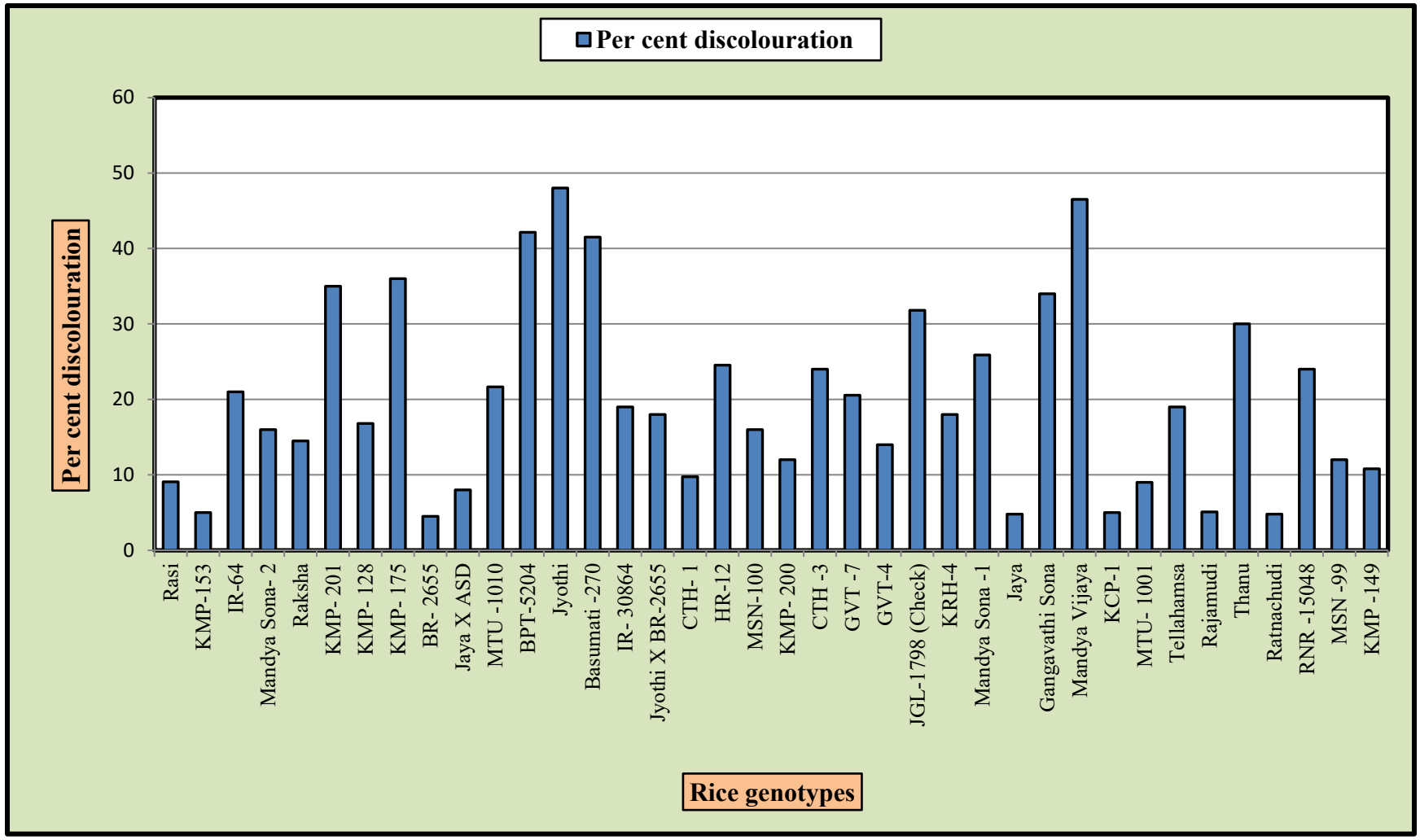


Fig.4.12. Reaction of different rice genotypes screened under natural condition against grain discolouration during *Kharif* 2017

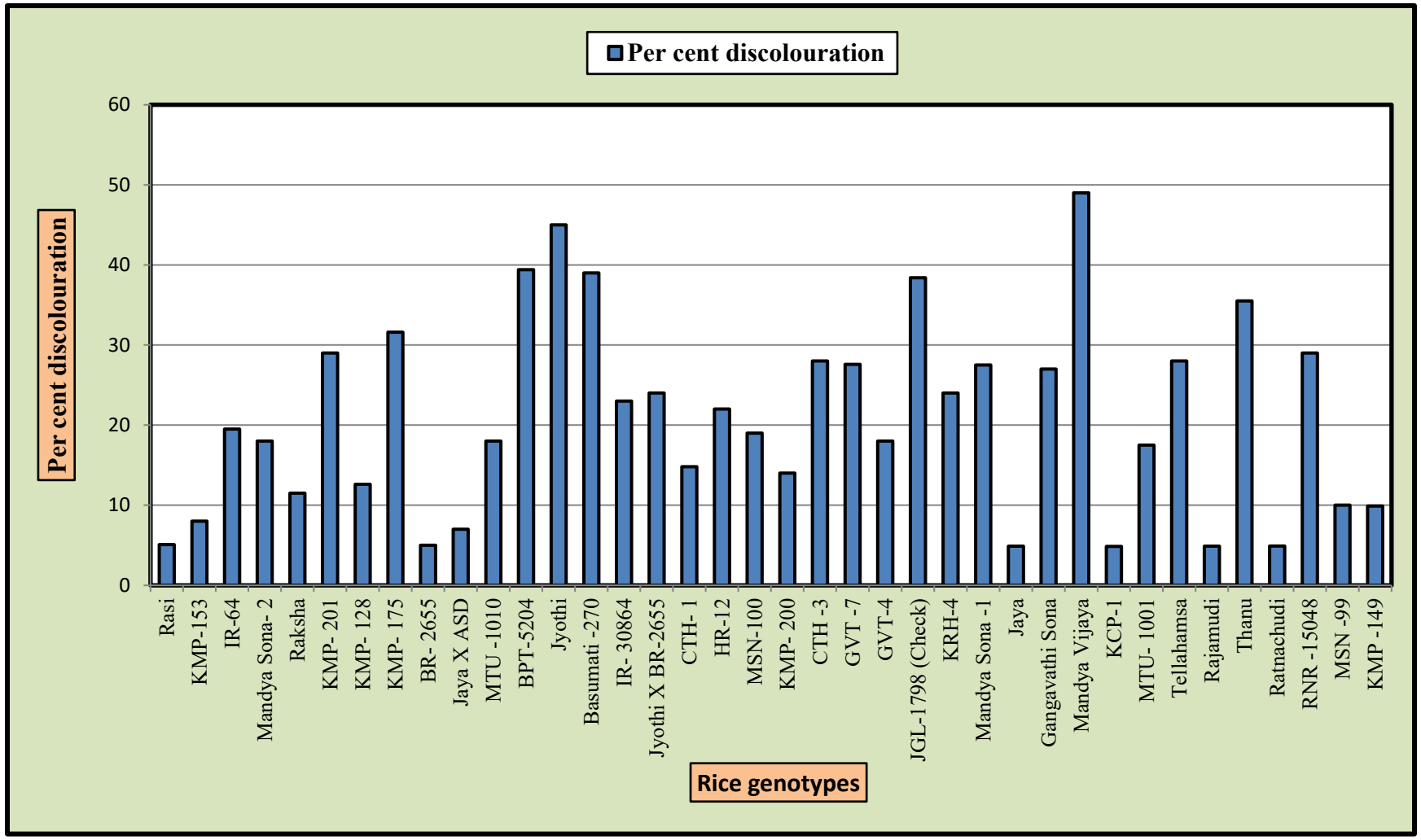


Fig.4.13. Screening of rice genotypes against grain discolouration during *Kharif* 2018 in Yalandur taluk of Chamarajanaggara district

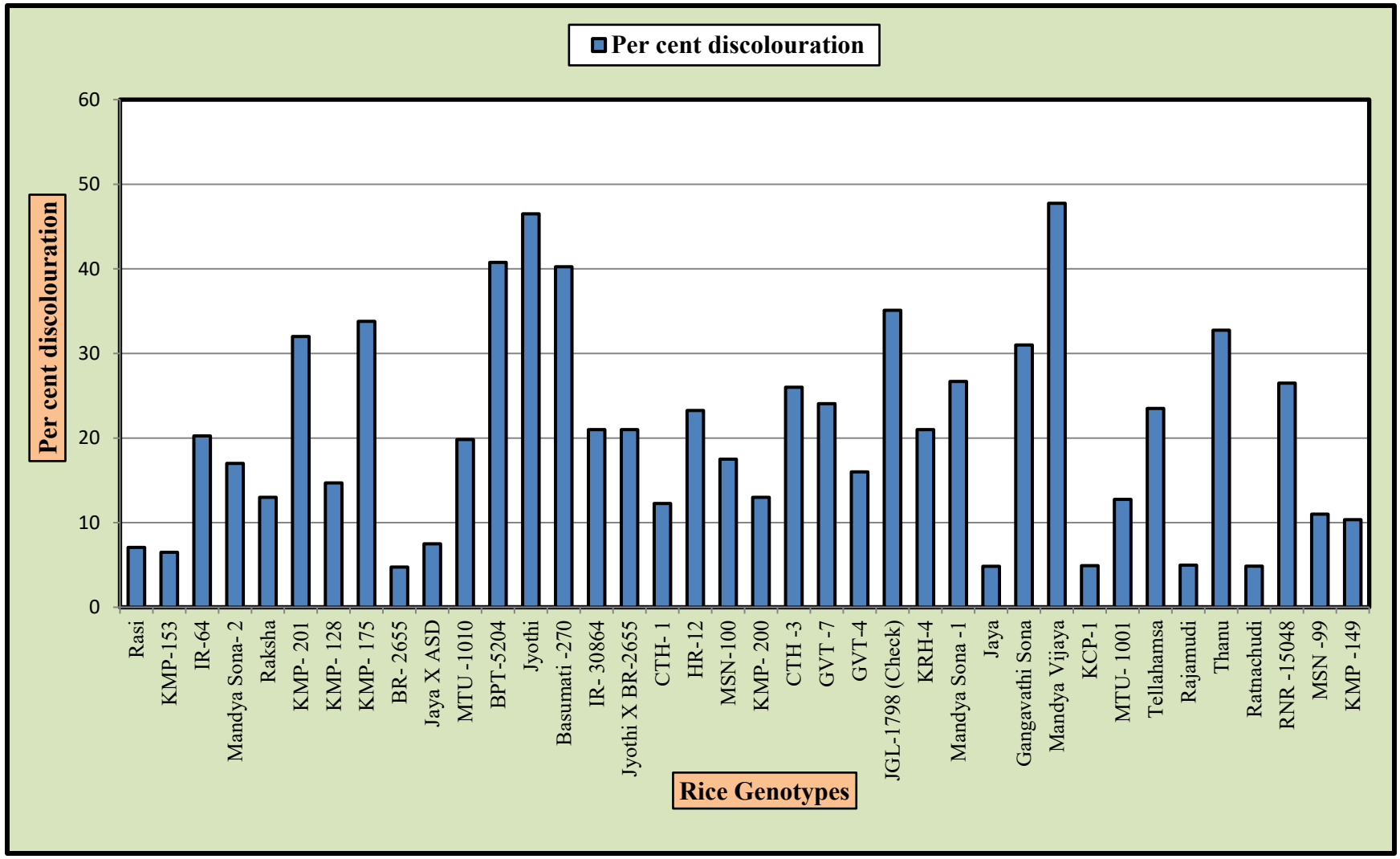


Fig.4.14. Reaction of different rice genotypes were screened against grain discoloruration during *Kharif* 2017and 2018 (Mean)

due to presence oftemperature ranged from 17.16 to 31.02 °C and relative humidity of 51.34 to 88.29 % leading to higher grain discolouration. The results are in acceptance with Duraiswamy and Mariyappan (1983) and Dash and Narain (1998). They reported that higher rainfall and more humidity favoured the deposition of fungal propagules. These conditions also increased the duration of flower opening which predisposed the crop to infection of grain discolouration.

Table 4.14. Differential reaction of rice genotypes against rice grain discolouration by using standard evaluation scale 0 - 9

Disease rating scale	Response	No. of genotypes	Name of Genotypes
0	Immune	-	-
1	Resistant	-	-
3	Moderately Resistant	5	KCP-1, BR- 2655, Rajamudi, Jaya and Ratnachudi
5	Moderately susceptible	21	HR-12, Rasi, IR-64, Mandyasona- 2, Raksha, KMP-128, KMP-153, MTU-1010, IR-38064,CTH-1, MSN-100, Jaya X ASD, KMP-200, GVT-7, GVT-4, KRH-4, MSN-99, MTU-1001, Tellahamsa, KMP-149, Jyoti X BR-2655,
7	Susceptible	12	KMP-201, KMP-175, BPT-5204, Jyothi, Basumati-270, JGL 1798, Mandya Sona-1, Gangavati Sona Mandya Vijaya, Thanu, RNR - 15048 and CTH- 3
9	Highly susceptible	-	-

Totally 38 rice genotypes comprising short (5), medium (26) and long duration (7) were screened against grain discolouration during *Kharif* 2017 and 2018 in farmers field at Yalandur taluk, Chamarajanagara district. The field experiment was taken up in the irrigated ecosystem. Due to delay in release of water to sub canals usual farming activities were taken up in the month of August. Hence, during *Khraif*2017 and 2018, the nursery activity was taken up in fourth week of August and transplanting was done in third week of September. Further, the recommended dose of fertilizers was applied as per

UASB package and the no chemical pesticides were applied in the experimental plot. The per cent disease incidence was recorded at every 15 days interval since planting to harvesting stage in all tested genotypes. Further, the weather data of experimental plot during *Kharif* 2017 and 2018 were recorded at Regional Agricultural Research Station, Chamarajanagara. Later, studied the effect of weather parameters on per cent disease incidence of all 38genotypes tested and the results are presented in (Table 3.4, 4.15, Fig.4.15). The mean data of *Kharif* 2017 and 2018 revealed that, among short, medium and long duration genotypes, the mean per cent disease incidence has ranged from 14.26 to 24.69. The higher mean average incidence of disease (24.69 %) was noticed in long duration genotypes next to medium (21.39 %) and short (14.26 %) duration. The average weather parameters of *Kharif* 2017 and 2018 were recorded *viz.*, mean rainfall 419.9 mm, maximum temperature 31.02 °C, minimum temperature 17.16 °C, maximum relative humidity (88.29%) and minimum relative humidity (51.34%). During *Kharif* 2017 and 2018, the short duration genotypes like Rasi, Raksha, MTU-1010, RNR-15048 and KCP-1 were showed varied per cent incidence from 4.92 to 26.50,but mean per cent disease incidence was 14.26.The lower incidence of disease in short duration genotype was due to exposure of crop to weather factors in shorter period varied from 110 to 120 days beside that these genotypes were having higher phenol content ranged from 62.98 to 67.76 mg /g. Whereas, the medium duration genotypes *viz.*, IR- 64,MTU- 1001,Thanu, Jaya X ASD, Tellahamsa, IR- 30864, KMP-200, Jyothi, Jyothi X BR-2655, MSN 100, CTH-1, CTH-3, KMP-201, GVT-7, GVT-4, HR-12, KMP-175, KMP-153, KMP-128, KMP-149, Mandya Sona- 1,Mandya Sona- 2,Gangavathi Sona, JGL- 1798, MSN 99 and KRH- 4 were showed varied per cent disease incidence from 6.50 to 46.50 amd mean average disease incidence was 21.69. The variation in incidence of disease in these genotypes was due to presence of variation in phenol content and whilc was ragned from 56.32 to 67.76 mg /g.The long duration genotyeps like BR- 2655,Rajamudi, Ratnachudi, Jaya, Mandya Vijaya, BPT-5204 and Basumathi-270 were showed variation in per cent incidence of disease from 4.75 to 47.75. But, the highest incidence of disease noticed in Mandya Vijaya (49.00 %) and mean average per cent disease incidence was 24.69.Among long duration genotypes, the genotype like BR -2655 and Jaya were coarse grain type and BPT-5204, Rajamudi, Ratnachudi and Basumathi-270 were fine quality.The higher incidence of disease in these fine grain genotypes might be due to

		
Healthy grains	**BR-2655 (Moderately Resistant)**	**Discoloured grains**
		
Healthy grains	**Rasi (Moderately susceptible)**	**Discoloured grains**
		
Healthy	**Mandya Vijaya (Susceptible)**	**Discoloured**

Plate 9. Differential reaction of rice genotypes against rice grain discolouration using standard evaluation system scale 0 - 9

		
Healthy	**Jyothi (Susceptible)**	**Discoloured**
		
Healthy	**JGL-1758 (Susceptible)**	**Discoloured**

Plate 9a. Differential reaction of rice genotypes against rice grain discolouration using standard evaluation system scale 0-9

Table 4.15. Effect of weather parameters on incidence of grain discolouration in short, medium and long duration rice genotypes

Sl. No.	Genotypes	Weather parameters (Cropping period)					Disease incidence (%)			
		Mean Rainfall (mm) (2017 and 2018)	Mean Temperature (°C) (2017 and 2018)		Mean R.H (%) (2017 and 2018)		2017	2018	Mean	Mean average Per cent disease incidence
			Max.	Min.	Max.	Min.				
Short duration (120 -125 days)										
1	Rasi	419.9	31.02	17.16	88.29	51.34	9.08	5.08	7.08	14.26
2	Raksha						14.50	11.50	13.00	
3	MTU- 1010						21.66	18.00	19.83	
4	RNR- 15048						24.00	29.00	26.50	
5	KCP-1						5.00	4.85	4.92	
Medium duration (130 -135 days)										
1	IR- 64	419.9	31.02	17.16	88.29	51.34	21.00	19.50	20.25	21.39
2	Mandya Sona- 2						16.00	18.00	17.00	
3	MTU- 1001						9.00	17.50	12.75	
4	KRH- 4						18.00	24.00	21.00	
5	JGL- 1798						31.80	38.40	35.10	
6	Mandya Sona- 1						25.88	27.50	26.69	
7	Gangavathi Sona						34.00	27.00	31.00	
8	KMP-149						10.80	9.90	10.35	
9	Thanu						30.00	35.50	32.75	
10	Tellahamsa						19.00	28.00	23.50	
11	Jyothi						48.00	45.00	46.50	
12	MSN 99						12.00	10.00	11.00	
13	MSN 100						16.00	19.00	17.50	
14	IR- 30864						19.00	23.00	21.00	

Sl. No.	Genotypes	Weather parameters (Cropping period)					Disease incidence (%)			
		Mean Rainfall (mm) (2017 and 2018)	Mean Temperature (°C) (2017 and 2018)		Mean R.H (%) (2017 and 2018)		2017	2018	Mean	Mean average Per cent disease incidence
			Max.	Min.	Max.	Min.				
15	CTH-1						9.75	14.80	12.27	
16	CTH-3						24.00	28.00	26.00	
17	KMP-153						5.00	8.00	6.50	
18	KMP-128						16.80	12.60	14.70	
19	KMP-175						36.00	31.60	33.80	
20	Jaya X ASD						8.00	7.00	7.50	
21	Jyothi X BR-2655						18.00	24.00	21.00	
22	KMP-200						12.00	14.00	13.00	
23	GVT-7						20.55	27.58	24.06	
24	GVT-4						14.00	18.00	16.00	
25	HR-12						24.53	22.00	23.26	
26	KMP-201						35.00	29.00	32.00	
Long duration (140 – 160 days)										
1	BR- 2655						4.50	5.00	4.75	
2	Rajamudi						5.08	4.88	4.98	
3	Ratnachudi						4.80	4.90	4.85	
4	Jaya	419.9	31.02	17.16	88.29	51.34	4.80	4.88	4.84	24.69
5	Mandya Vijaya						46.50	49.00	47.75	
6	BPT-5204						42.14	39.40	40.77	
7	Basumathi-270						41.50	39.00	40.25	

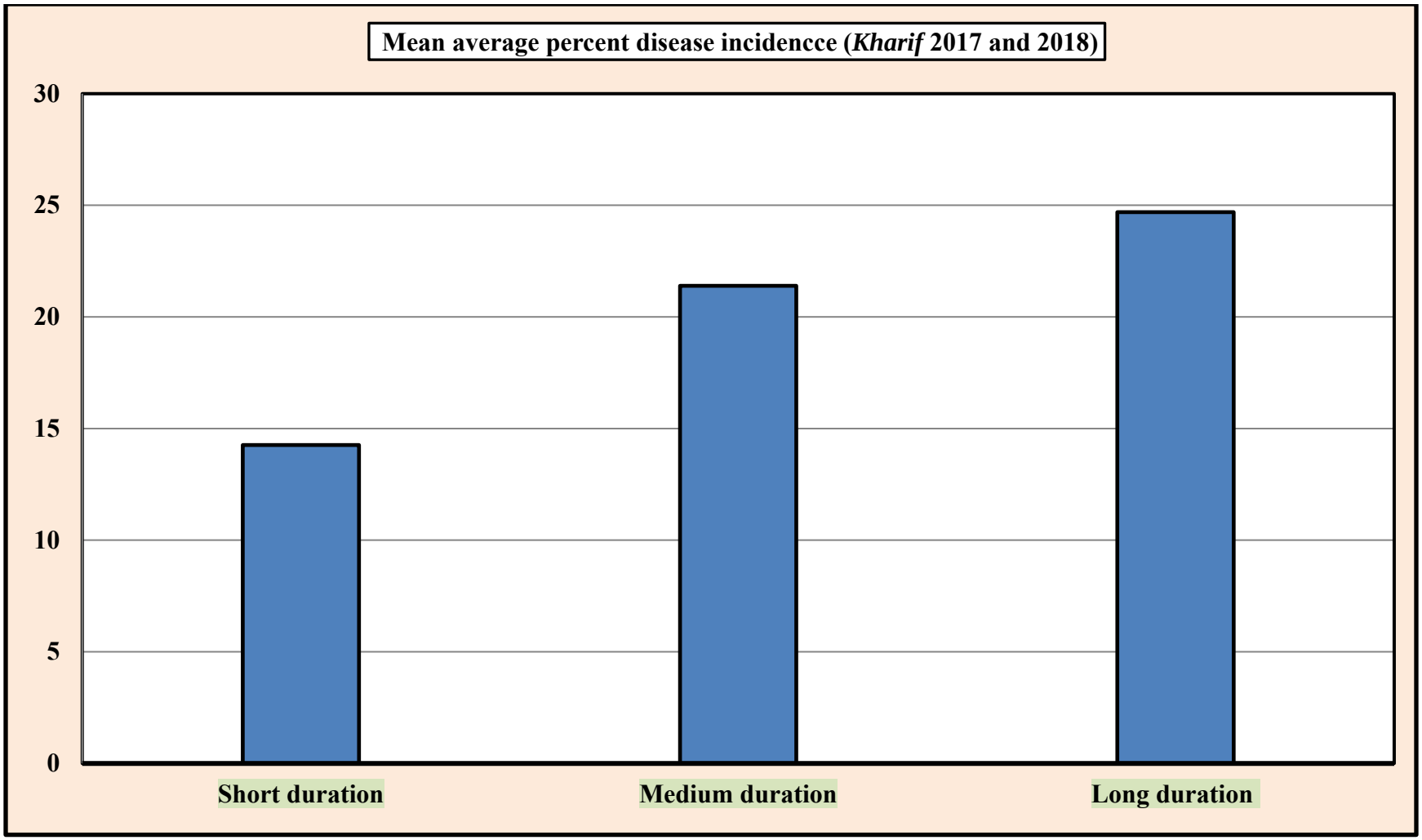


Fig. 4.15. Mean average per cent disease incidence of short, medium and long duration rice genotypes during *Kharif* 2017 and 2018

presence of lower amount of phenol content 56.86 mg /g. The present findings are in acceptance with Duraiswamy and Mariyappan (1983) and Dash and Narain (1998), and they reported that higher rainfall and more humidity favoured the deposition of fungal propagules.

4.6 Biochemical constituents and its effect on grain discolouration of rice

Research on biochemical mechanisms of resistance is prominent in the last four decades and is still being persuaded along with renewed emphasis on histology, including use of histological methods. In general, infection by some pathogens causes a lot of changes in the biochemical pathways that are very vital in rice grains. This led to various fluctuations of biochemical constituent's *viz.*, total phenols, total sugar; reducing and non reducing in infected grains but the impact varies among different genotypes. Therefore, the biochemical constituents like phenols, total sugar, reducing sugar and non reducing sugar of twenty-two rice grain samples (healthy and discoloured) procured from three different ecosystem were analyzed by using standard procedures as described in material and methods.

4.6.1 Total Phenols

Phenolic compounds have the biological properties of antimicrobial activity and play a major role in plants to act as protective compounds against various disease-causing agents *viz.*, fungi, bacteria and viruses. Estimation of total phenol was done by Folinciocalteau reagent method. Results indicated that, the quantity of total phenols per gram of healthy and discoloured grains of all rice genotypes were showed variation. Significantly higher phenol content was observed in discoloured grains that varied from 44.86 to 76.87 mg/g than that of the healthy grains that ranged from 39.74 to 64.10 mg/g (Table 4.16).

Total phenol content showed variation in moderately resistant, moderately susceptible and susceptible genotypes. Whereas, the total phenol content was recorded maximum in moderately resistant genotypes *viz.*, BR-2655 (64.10 mg/g in healthy, 76.87 mg/g in diseased samples) followed by Jaya (63.76 mg /g in healthy,75.09 mg/g in

Table 4.16. Total phenol content of healthy and discoloured grains of different rice genotypes

Sl. No.	Rice samples				
		Total phenol content (mg/g)		Per cent increased over healthy	Mean per cent increase over healthy
		Healthy	Diseased		
	Moderately resistant genotypes				
1	BR-2655	64.10	76.87	19.92	18.84
2	Jaya	63.76	75.09	17.76	
	Moderately susceptible genotypes				
3	IR-64	51.77	61.87	19.50	17.55
4	Rasi	55.76	64.98	16.53	
5	Super Aman	47.76	57.75	20.90	
6	Jayshree	45.76	55.98	22.33	
7	Jayakrishna	44.98	53.87	19.76	
8	Hemavathi	51.09	59.96	17.36	
9	Nellur Sona	39.79	48.41	21.66	
10	KMP-105	49.09	57.87	17.88	
11	MTU-1010	52.88	61.76	16.79	
12	KRH-4	56.87	66.08	10.69	
13	Abhilash	50.41	59.09	17.21	
14	Intan	49.08	57.54	17.23	
15	Thanu	48.87	53.91	10.31	
16	Kaje Jaya	44.12	50.76	15.04	
17	MTU-1001	51.77	61.87	19.50	
18	Kaveri Sona	43.97	51.96	18.17	
	Susceptible genotypes				
19	BPT-5204	39.74	44.86	12.88	12.68
20	Gangavathi Sona	45.55	51.32	12.66	
21	RNR-15048	51.55	57.98	12.47	
22	Jyothi	49.65	55.98	12.74	
-	S EM +_	0.51	0.35	-	-
	CD @ 5 %	1.49	0.50		
	CV (%)	1.11	1.03		
	SEd	0.72	1.00		

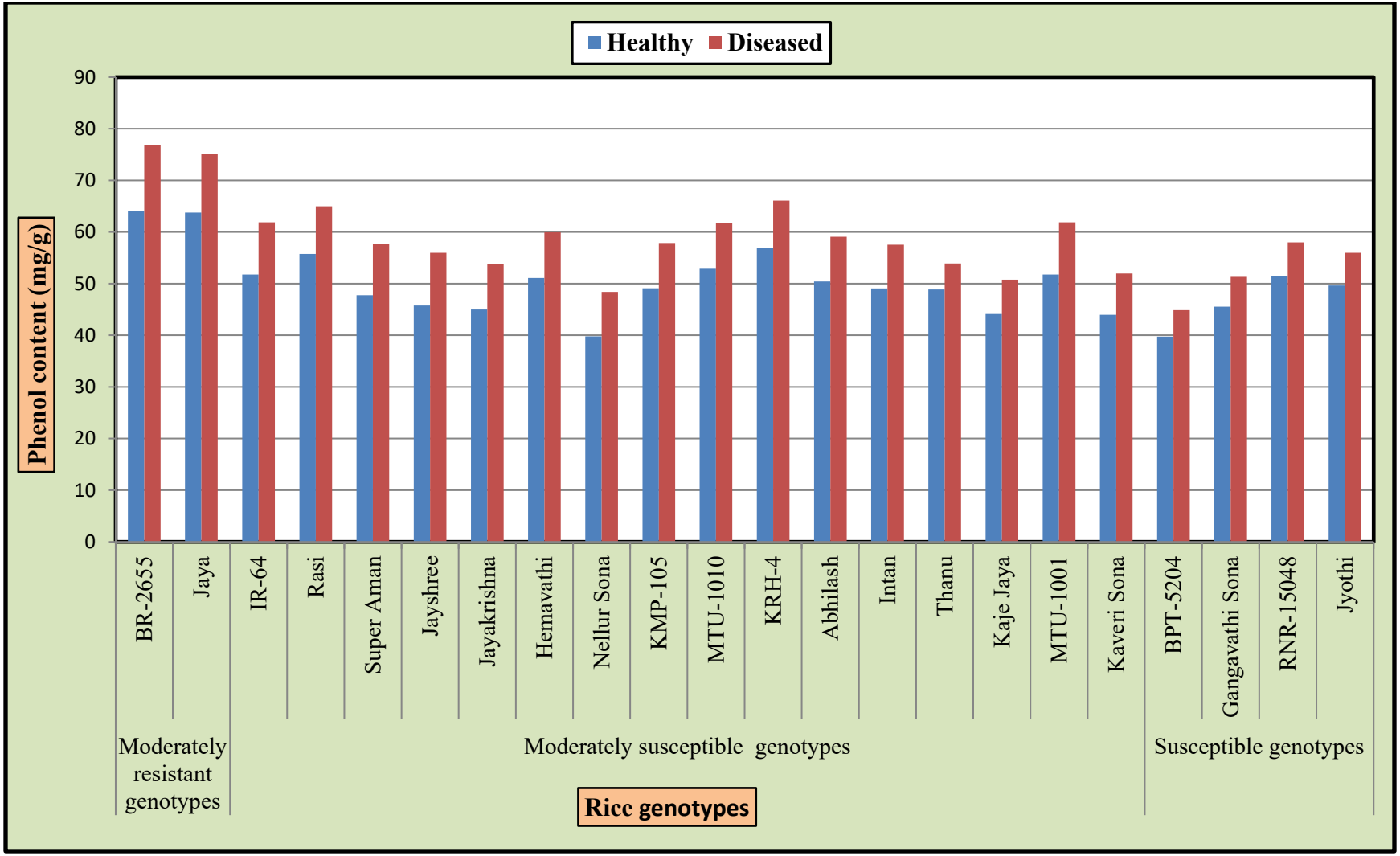


Fig. 4.16. Total phenol content (mg/g) of healthy and discoloured grains of different rice genotypes

diseased samples) as compared to rice genotypes having moderately susceptible and susceptible reaction. The mean per cent increased phenol content in samples of discoloured grain over healthy grain samples were noticed higher in moderately resistant rice genotypes (18.84%) as compared to moderately susceptible (17.55%) and susceptible genotypes (12.68%). Among the moderately susceptible genotypes, the total phenol content was noticed higher in diseased grain samples (66.08 mg/g) and healthy (56.87 mg/g) of KRH-4 and lowest phenolic content was observed in Nellur Sona (48.41 mg /g, diseased; 39.79 mg/g, healthy). In case of susceptible genotypes, the phenol content was recorded as highest in RNR-15048 (57.98 mg/g, diseased; 51.55 mg/g, healthy) and lowest in BPT-5204 (44.86 mg/g, diseased; 39.74 mg/g, healthy) (Table 4.16, Fig.4.16). The total phenol content was found higher in diseased grain samples as compared to healthy grain samples in all the rice genotypes. The same trend was observed in moderately resistant genotypes, moderately susceptible and susceptible genotypes.

The observed variation in phenolic content among the genotypes studied here may be due to variations in the gentetic makeup that causes variations in the host immunity which is evident from the changes in phenolic content. The results of the investigations on phenols are in acceptance with Duraiswamy and Mariappan, (1983) who reported that, the rice grains infected with *Curvularia lunata* and *Heliminthosporium oryzae* showed higher level of phenol content. The high phenol content was observed in infected rice grain through a PPO-PO-H_2O_2 system in which the phenol compounds get oxidized and confers resistance (Srivastava, 1987). The phenol content in rice genotypes were reported to be varied from 7.67 % to 70.78 % when rice grains infected with *S.oryzae* and phenol content significantly increased in all age group of rice plants when inoculated with *Sarocladiumoryzae* due to activation of defense mechanism to the site of infection. (Raja and Syamala, 2012, Gopalakrishnan *et al*., 2010 and Velazhahan and Ramabadran, 1993). The increased enzymatic activity of polyphenol oxidase and peroxidase leads to increase in the phenol content in discoloured rice grains (Khatun *et al*., 2009). In general, the total phenol content was found significantly higher in discoloured grains than that in healthy grains. (Divya, 2015)

4.6.2 Total Sugars

Total sugars were analyzed by following Anthrone method in twenty-two genotypes collected across three ecosystems. The healthy grains have recorded lower total sugar content as compared to diseased grains and total difference in sugar content in healthy and discoloured grains among rice varieties were statistically significant. Among the healthy grains, total sugar content ranged from 20.65 to 28.82 mg/g, whereas in discoloured grains, it ranged from 22.87 to 34.82 mg/g .The maximum sugar content was recorded in BPT-5204 in healthy (28.82 mg /g) and diseased (34.82 mg/g) grains and minimum sugar content of healthy (20.65 mg/g) grains and in diseased (22.87 mg/g) was recorded in IR-64**(**Table 4.17, Fig. 4.17). The increase in per cent total sugar content in discoloured grains over healthy grains ranged from 8.74 to 18.74. The highest variation was noticed in BPT-5204 (18.74%) and lowest was recorded in KRH-4 (8.74%). The mean per cent total sugar content was found high in discoloured grains over healthy grains and the trend was noticed in all susceptible genotypes (18.22%), moderately susceptible (11.54%) and in moderately resistant genotypes (10.39%). The increase in total sugar content was more in diseased grains than healthy grains in all rice genotypes which was observed mainly because of the requirement of more sugars by the infected pathogens for pathogenesis and further development within the host tissue (Duraiswamy and Mariappan, 1983 and Saifulla*et al.*1998).

4.6.3 Reducing sugars

The results shown in the table 4.17 and Fig.4.18 revealed that, the differences in reducing sugar content in healthy and discoloured grains of all tested rice genotypes were found statistically significant. The reducing sugar content in all diseased grain samples had ranged from 13.68 to 29.55 mg/g and 12.67 to 24.43 mg/g in healthy samples. Among, the healthy grain samples (22), the highest reducing sugar content were recorded in BPT-5204 (24.43 mg/g) and the lowest in BR-2655 (12.67 mg/g). Whereas, diseased grain samples recorded the highest reducing sugar content in BPT-5204 (29.55 mg/g) and lowest in BR-2655 (13.68 mg/g,). The per cent increases of reducing sugars in diseased grains over healthy grains were varied among all genotypes but it was noticed highest in BPT-5204 (24.43%) and least in BR-2655 (7.97%). Whereas, the mean per cent increase

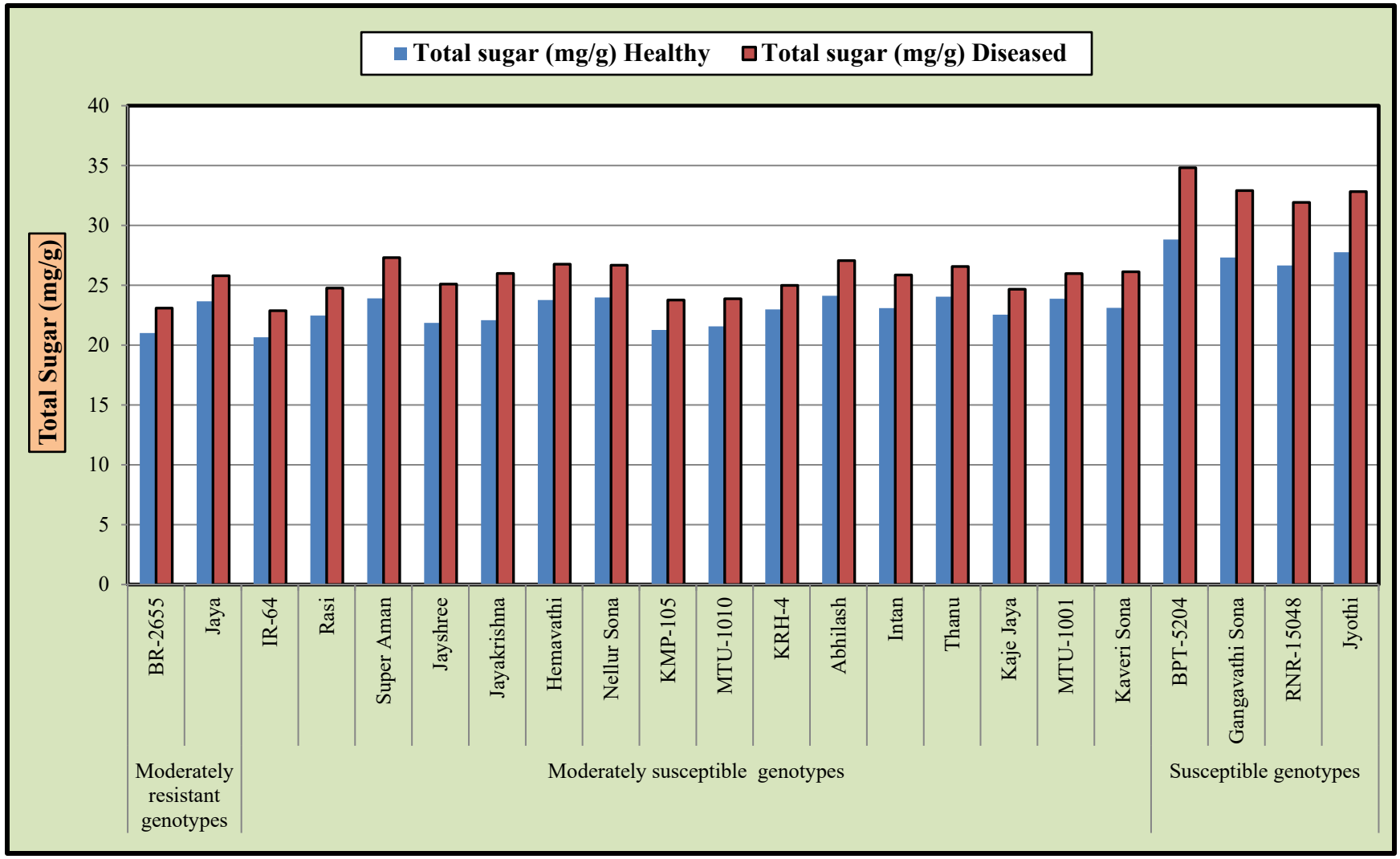


Fig. 4.17. Total sugar content (mg/g) of healthy and discoloured grains of different rice genotypes

Table 4.17. The reducing, non reducing and total sugar content in the healthy and discoloured rice grains of different rice genotypes

Sl. No.	Rice samples												
	Moderately resistant genotypes												
		Reducing sugar (mg/g)				Non reducing sugar (mg/g)				Total sugars (mg/g)			
		Healthy	Diseased	% increased over healthy	Mean	Healthy	Diseased	% increased over healthy	Mean	Healthy	Diseased	% increased over healthy	Mean
1	BR-2655	12.67	13.68	7.97	9.03	8.34	9.41	12.82	10.03	21.01	23.09	10.99	10.39
2	Jaya	14.56	16.03	10.09		9.10	9.76	7.25		23.66	25.79	9.80	
	Moderately susceptible genotypes												
3	IR-64	14.12	16.32	15.58	13.92	6.53	7.29	11.63	8.98	20.65	22.87	10.75	11.54
4	Rasi	13.94	15.50	11.11		8.53	9.26	9.84		22.47	24.76	11.01	
5	Super Aman	16.43	19.08	16.12		7.47	8.40	12.14		23.90	27.30	14.22	
6	Jayshree	16.10	18.90	17.39		5.75	6.17	7.30		21.85	25.09	14.82	
7	Jayakrishna	16.45	19.34	17.56		5.63	6.64	17.93		22.08	25.98	13.13	
8	Hemavathi	16.67	18.97	13.79		7.09	7.79	9.87		23.76	26.76	12.62	
9	Nellur Sona	16.34	18.44	12.85		7.64	8.23	7.72		23.98	26.67	11.21	
10	KMP-105	15.65	17.15	9.58		5.61	6.61	17.82		21.26	23.76	11.75	
11	MTU-1010	13.99	15.76	12.65		7.57	8.11	7.13		21.56	23.87	10.71	
12	KRH-4	12.86	14.43	12.20		10.12	10.56	4.34		22.98	24.99	8.74	
13	Abhilash	15.42	17.86	15.82		8.70	9.20	5.74		24.12	27.06	12.10	
14	Intan	15.45	17.99	16.44		7.64	7.87	3.01		23.09	25.86	11.99	
15	Thanu	14.98	16.89	11.27		9.06	9.67	6.73		24.04	26.56	10.48	
16	Kaje Jaya	15.55	17.06	9.71		6.99	7.61	8.86		22.54	24.67	9.44	
17	MTU-1001	13.97	15.65	12.02		9.90	10.32	4.24		23.87	25.97	8.79	
18	Kaveri Sona	15.55	17.84	14.72		7.56	8.28	9.52		23.11	26.12	13.02	

Sl. No.		Reducing sugar (mg/g)				Non reducing sugar (mg/g)				Total sugars (mg/g)			
		Healthy	Diseased	% increased over healthy	Mean	Healthy	Diseased	% increased over healthy	Mean	Healthy	Diseased	% increased over healthy	Mean
	Susceptible genotypes												
19	BPT-5204	24.43	29.55	24.43	21.05	4.39	5.27	20.04	18.08	28.82	34.82	18.64	18.22
20	Gangavathi Sona	22.56	27.45	21.67		4.76	5.46	14.70		27.32	32.91	18.12	
21	RNR-15048	20.43	24.67	20.75		6.22	7.25	16.55		26.65	31.92	18.05	
22	Jyothi	21.21	24.89	17.35		6.55	7.93	21.06		27.76	32.82	18.22	
	S EM ±	0.16	0.24	-	-	0.12	0.14	-	-	0.11	0.17	-	-
	CD @ 5 %	0.46	0.67			0.33	0.41			0.32	0.49		
	CV (%)	1.17	0.33			1.29	1.51			0.68	0.96		
	SEd	0.23	0.33			0.16	0.20			0.16	0.24		

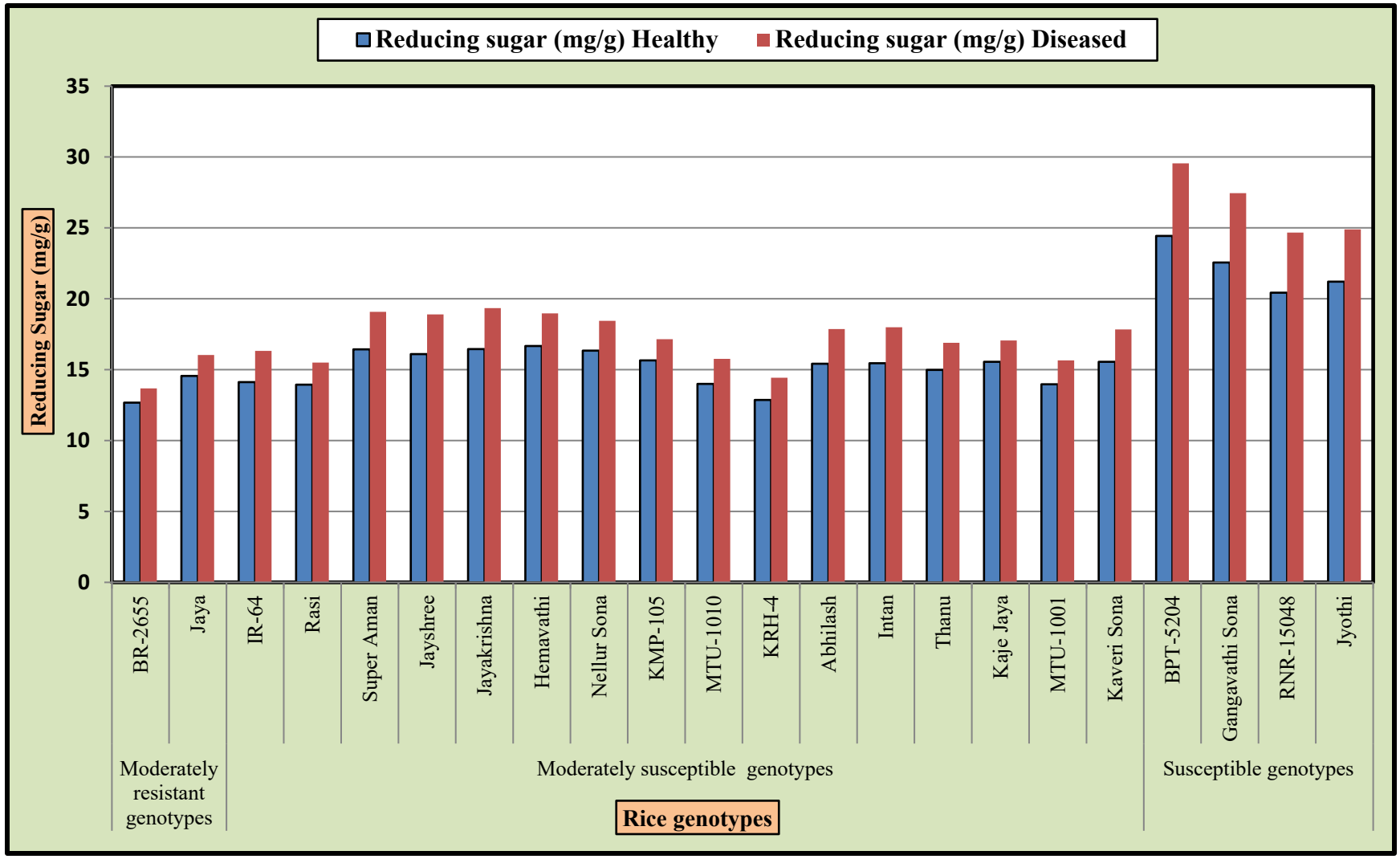


Fig.4.18. Reducing sugar content (mg/g) of healthy and discoloured grains of different rice genotypes

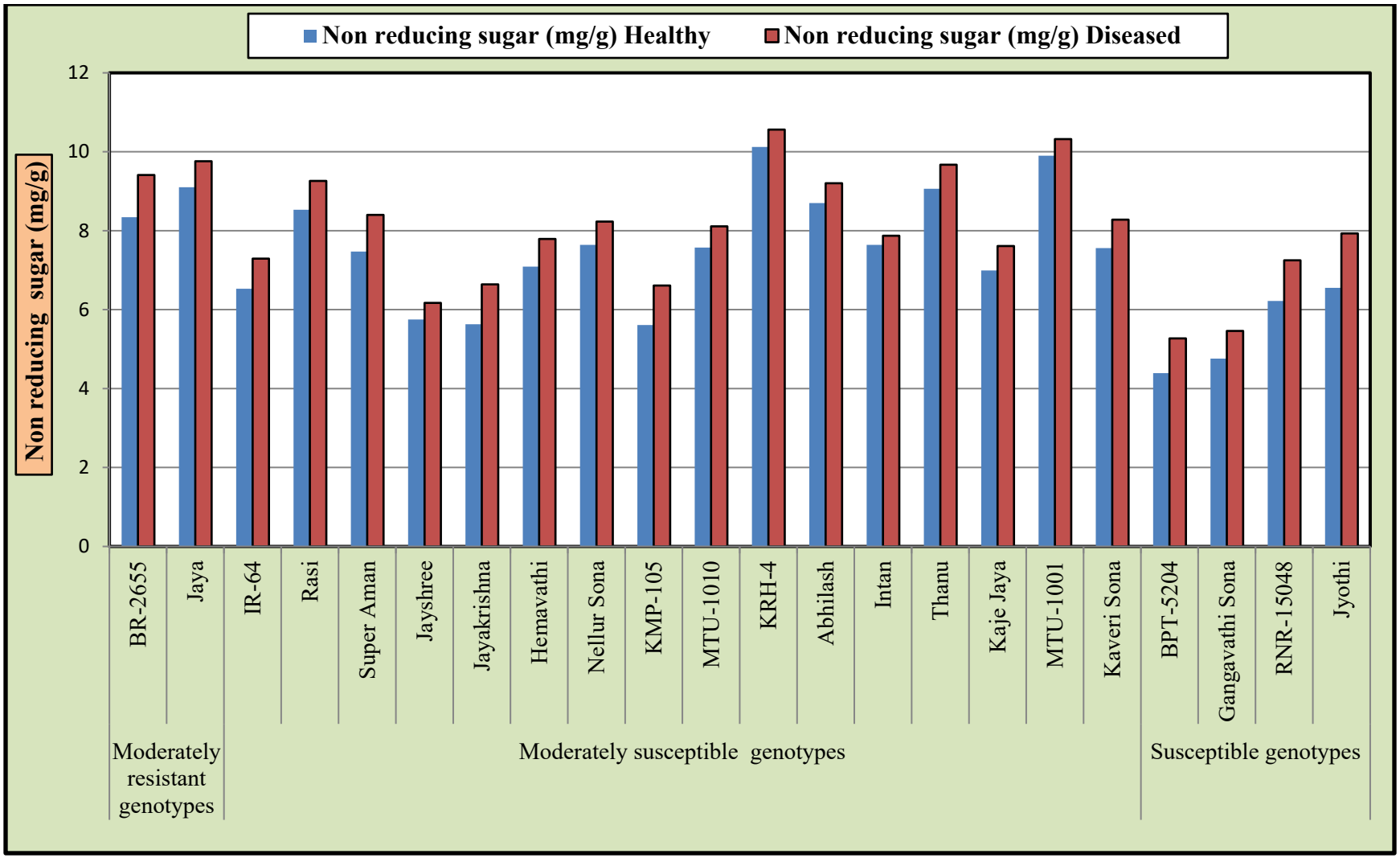


Fig.4.19. Non reducing sugar content (mg/g) of healthy and discoloured grains of different rice genotypes

in reducing sugar was found high in diseased grains over healthy grains, in which susceptible genotypes had (21.05%) followed by moderately susceptible (13.92%) and moderately resistant genotypes (9.03%).The higher level of reducing sugars noticed in healthy and diseased grains of BPT-5204 can be attributed to the fact that with susceptibility of grain disease as the pathogens require more reducing sugars for pathogenesis process and further development in host tissues. Lower sugar level noticed in BR-2655 can be attributed to moderately resistant nature where, reducing sugars are not sufficiently available for the pathogens which lead to restriction of growth and development in host tissue. These finding are in acceptance with Saifulla*et al*. (1998) andDuraiswamy and Mariappan (1983).

4.6.4 Non reducing sugars

Among tested genotypes (22), the non reducing sugar level was found high in diseased samples over healthy grain samples. The range of non reducing sugars observed in diseased samples were; 5.27 mg/g to 10.56 mg/g and in healthy samples; 4.39 mg/g to 10.12 mg/g. In the case of non reducing sugar content in healthy grains, highest amount was observed in KRH-4 (10.12 mg/g) and lowest in BPT-5204 (4.39 mg/g). On the other hand, in discoloured grain, highest value was observed in KRH-4 (10.56 mg/g) and least in BPT-5204 (5.27 mg/g). The highest per cent increase of non reducing sugar was found in diseased grains of BPT-5204 (20.04%) and lowest increase in MTU -1001 (4.24 mg/g) (Table 4.17, Fig. 4.19). These results are in acceptance with Saifulla *et al*. (1998) and Duraiswamy and Mariappan (1983).

4.7 Management of grain discolouration in rice through fungicides and bio-agents

Chemical management by use of fungicides is an important tool for managing disease where the disease is already prevalent in the field. The continuous use of recommended fungicides in the management of disease may lead to development of resistance by pathogens against chemicals there by forcing to apply repeatedly and cause residual toxicity. on the alternate, bio control agents are environmentally nonpolluting, easily accessible, non phototoxic, readily biodegradable and relatively cost effective. Hence, in this field experiment more focus was on use of new molecules of fungicides

and bio-control agents. Evaluated four new molecules of fungicide and one bio-control agent against rice grain discoloration disease during *Kharif* 2017 and 2018 in farmers field in Y.K.Mole village, Yalandur taluk, and Chamarajanagara district. Randomized block design was followed in this study and it includes 16 treatments and three replications. These treatments were imposed on susceptible check (JGL-1798) and no spray was given except schedule of spray recommended by the committee.

Among sixteen treatments imposed, all the treatments tested were showed significantly superior disease reduction over control (Table 4.18, Fig.4.31). Mean per cent disease index ranged from 3.86% to 32.00%. Among fungicides, mean per cent disease index was ranged from 3.86 to 17.76 and for bio-fungicidesit was from 18.05 to 22.00. The mean yield was ranged from 40.54 to 56.33 q ha^{-1} and the incremental benefit cost ratio varied from 1:4.92 to 1:12.85 for chemicals fungicides, whereas it was ranged from 1: 2.48 to 1: 5.28 for bio fungicides

Results (Table 4.18) revealed that, disease severity among different treatments. The treatment of tebuconazole 50 % + trifloxystrobin 25% 75 WG @ 0.04% (T_6) both at panicle emergence stage and 15 days after panicle emergence has significantly lesser severity than other treatments by recording 3.86 per cent disease index followed by treatment of tebuconazole 50 % + trifloxystrobin 25% 75 WG @ 0.04% as a single spray at panicle emergence stage (T_4 - 4.80 per cent disease index) and panicle emergence stage after 15 days (T_5 - 6.65 per cent disease index).

Among chemical fungicides, severity (17.76%) of disease was in higher in treatment T_{11} (mancozeb 75% WP @ 0.2% sprayed at 15 days after panicle emergence stage) followed by treatment T_{10} (mancozeb 75% WP @ 0.2% spray at panicle emergence). Among bio-fungicides, least disease index of (18.05%) was observed in treatment T_{15} (*Pseudomonas fluorescens* @ 0.5% spray at panicle emergence and 15 days after panicle emergence) next to treatment T_{13} (*Pseudomonas fluorescens* @ 0.5% spray at panicle emergence) which recorded disease index of 19.86%. However, the highest grain yield (56.33 q ha^{-1}) was obtained in tebuconazole 50 % + trifloxystrobin 25% 75 WG @ 0.04% spray both at panicle emergence and after 15 days of panicle emergence

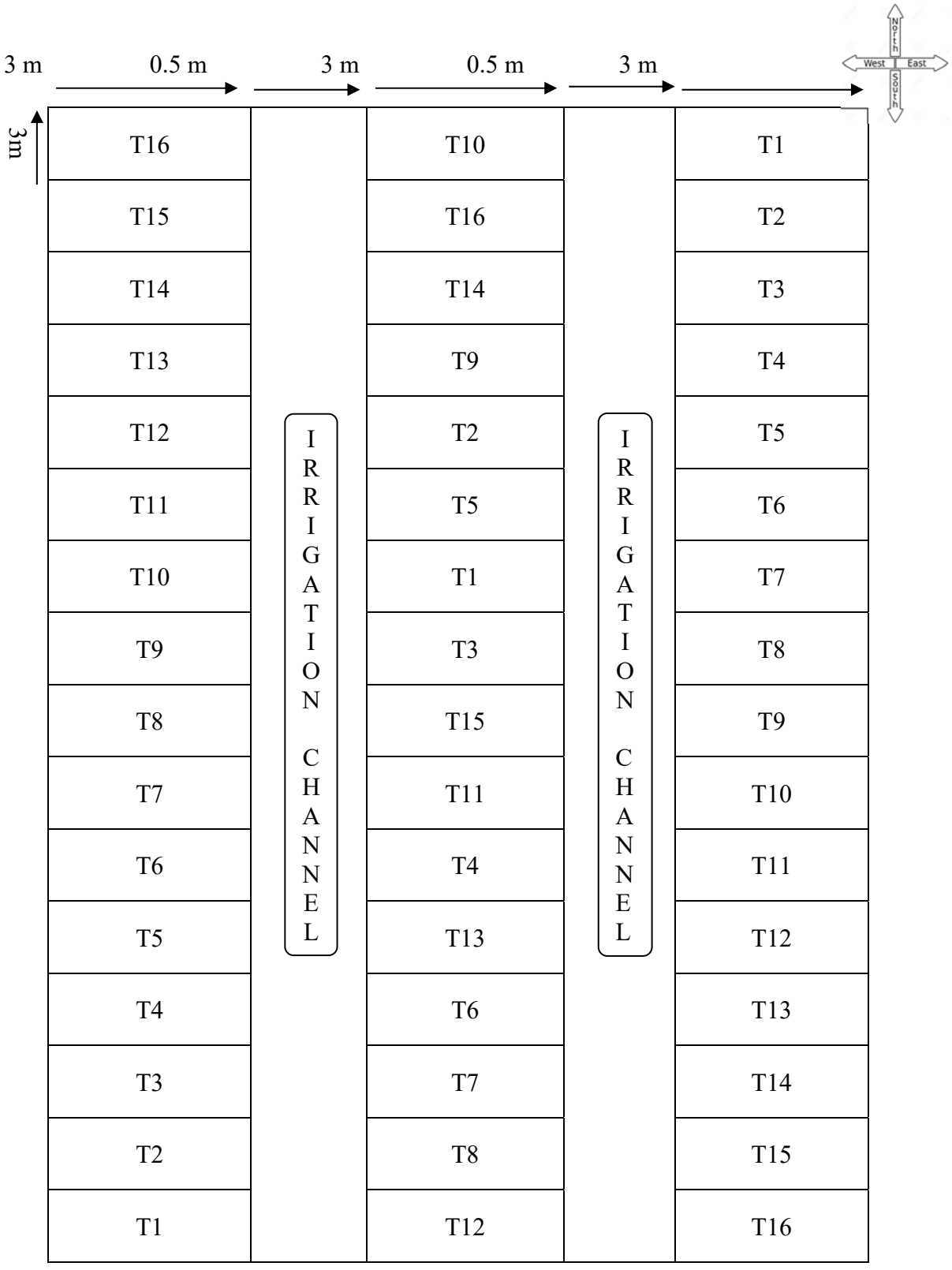


Fig.4.20. Layout of the field experiment for evaluation of fungicides and bio-control agents against rice grain discoloration disease in Y.K.Mole, Yalandur taluk, Chamarajanagara

treated plots and which was followed by tebuconazole 50 % + trifloxystrobin 25%75 WG @ 0.04% as a single spray at panicle emergence (54.31 q ha^{-1}) sprayed plots which also gave the highest per cent increase over control of 48% and 42%, respectively. The lowest grain yield was recorded with spray of *Pseudomonas fluorescens* @ 0.5% at 15 days after panicle emergence (41.25 q ha^{-1}). Among chemical fungicides, Mancozeb 75% WP @ 0.2% at 15 days after panicle emergence (42.65 q ha^{-1}) which was significantly lesser grain yield than in control plot (40.05 q ha^{-1}) (Table 4.18, Fig.4.21).

The highest incremental benefit to cost ratio of 1:12.85 was noticed in T_4 (tebuconazole 50 % + trifloxystrobin 25%75 WG @ 0.04% spray at panicle emergence) followed by 1:11.97 in treatment T_7 (hexaconazole 5% + captan 70% WP @ 0.2% spray at Panicle emergence) and 1: 11.63 in treatment T_1 (propiconozole @ 0.1% spray at panicle emergence). Whereas, the least incremental benefit to cost ratio among chemicals was 1:4.92 in treatment T_{11} (mancozeb 75% WP @ 0.2% spray after15 days of panicle emergence) and was 1:2.48 in treatment T_{14} (*Pseudomonas fluorescens* @0.5% spray at after15 days after panicle emergence)(Table 4.18, Fig.4.21).

When over all parameters *viz*., per cent disease index, yield and incremental benefit cost ratio are considered, the treatments including spray of tebuconazole 50% +trifloxystrobin 25% 75 WG @ 0.04% spray (T_6) at panicle emergence stage was significantly superior over other treatments by recording4.80 per cent disease index, grain yield of 54.31q ha^{-1} with benefit cost ratio of 1:12.85 followed by treatments including spray of hexaconazole 5% + captan 70 % WP @ 0.2% spray at panicle emergence (T_7) – 6.45 per cent disease index, grain yield of 51.56 q ha^{-1} with benefit cost ratio of 1:11.97) and (T_1) - propiconazole @ 0.1% at panicle emergence (T_1) -8.55 per cent disease index, grain yield of 48.85 q ha^{-1} with benefit cost ratio of 1 : 11.63) (Table 4.19).

During *Kharif 2*018, the results recorded that (Table 4.19, Fig. 4.32) 16 treatments were tested for management of rice grain discolouration. All the treatments were found significantly superior in reducing the severity of grain discolouration over untreated control. Mean disease severity was ranged from 3.98% to 31.05%. Lowest disease severity (3.98%) was found in tebuconazole 50 %+Trifloxystrobin 25% 75 WG @ 0.04%

Table 4.18. Management of grain discolouration in rice through fungicides and bio-fungicides during *Kharif* 2017 at Yalandur taluk, Chamarajanagara

Treatments	Percent disease index	Yield (q /ha)	Incremental benefit cost ratio
T_1- Propiconazole @ 0.1% at panicle emergence	8.55 (17.00)	48.85	1: 11.63
T_2- Propiconazole @ 0.1% at 15 days after panicle emergence	9.76 (18.20)	47.32	1 :9.49
T_3- $T_1 + T_2$	7.85 (16.27)	50.55	1: 7.00
T_4- Tebunconazole 50 %+ trifluoxystrobin 25% 75 \ WG0.04 % at panicle emergence	4.80 (12.66)	54.31	1: 12.85
T_5- Tebunconazole 50 %+trifluoxystrobin 25% 75 WG 0.04 % at 15 days after panicle emergence	6.65 (14.94)	52.65	1: 11.30
T_6- $T_4 + T_5$	3.86 (11.33)	56.33	1: 7.36
T_7- Hexaconazole 5% EC + captan 70 % WP @ 0.2% at panicle emergence	6.45 (14.71)	51.56	1: 11.97
T_8- Hexaconazole 5% EC + captan 70 % WP@ 0.2% at 15 days after panicle emergence	8.65 (17.10)	49.22	1: 9.34
T_9- $T_7 + T_8$	5.96 (14.13)	52.98	1: 6.69
T_{10}- Mancozeb @ 0.2% at panicle emergence	15.87 (23.48)	43.76	1: 7.51
T_{11}- Mancozeb @ 0.2% at 15 days after panicle emergence	17.76 (24.92)	42.65	1: 4.92
T_{12}- $T_{10} + T_{11}$	13.98 (21.96)	45.87	1: 6.21
T_{13}- *Pseudomonas fluorescens* @ 0.5 % at panicle emergence	19.86 (26.46)	42.05	1: 5.28
T_{14}- *Pseudomonas fluorescens* @ 0.5 % at 15 days after panicle emergence	22.00 (27.97)	41.25	1: 2.48
T_{15}- $T_{13} + T_{14}$	18.05 (25.14)	43.55	1: 3.51
T_{16}- Control	32.00 (34.45)	40.54	-
S EM ±	0.44	0.30	-
CD @ 5 %	1.26	0.42	-
CV (%)	3.79	0.90	-
SEd	0.62	0.89	-

(*Values in parenthesis are arc sine transformed value)

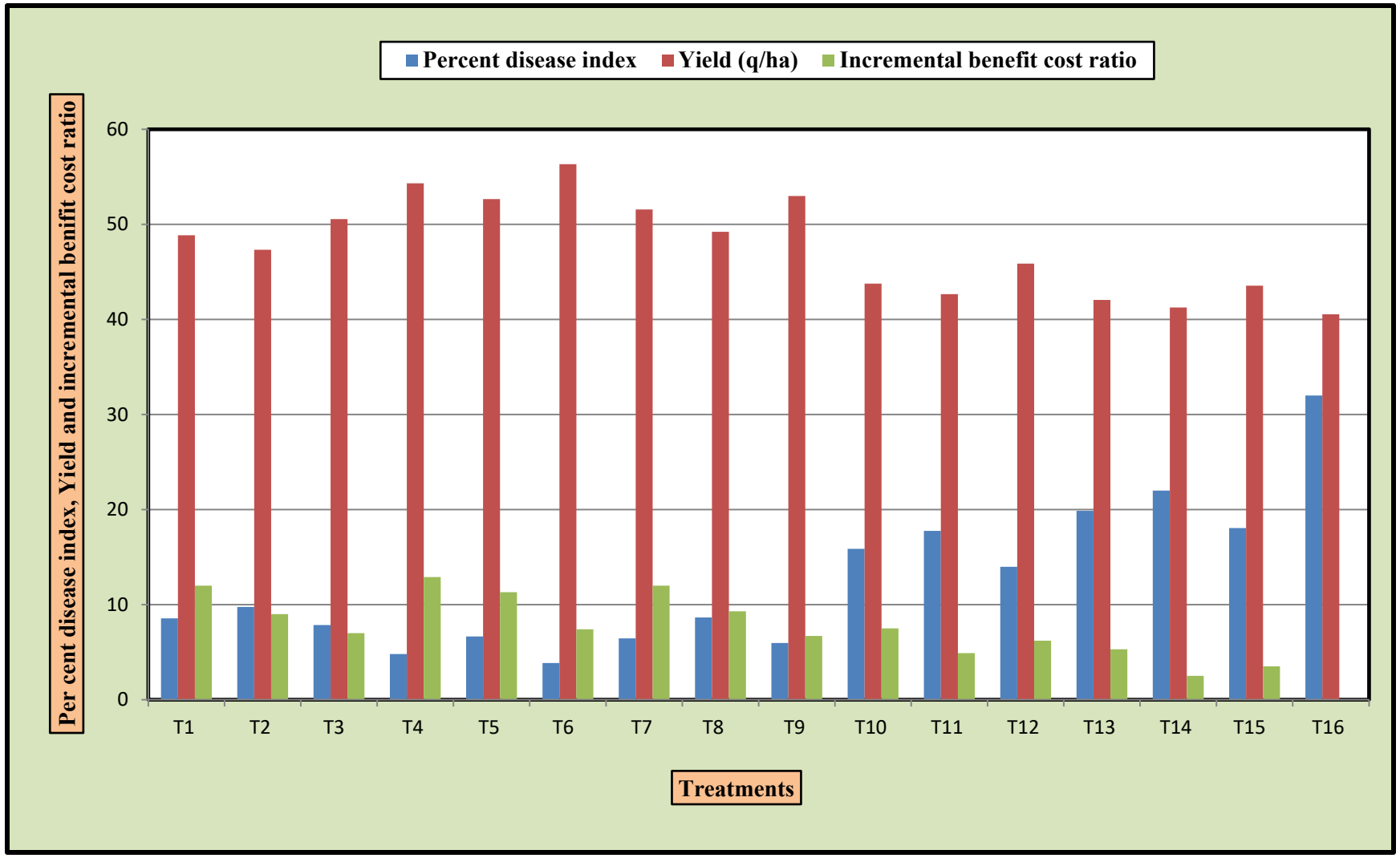


Fig. 4.21. Field evaluation of fungicides and bio-fungicide against rice grain discolouration disease

sprayed at panicle emergence and 15 days after panicle emergence followed by tebuconazole 50 % + trifloxystrobin 25% 75 WG @ 0.04% sprayed at panicle emergence stage (4.51 % disease index) and hexaconazole 5% + captan 70% 75 WP @ 0.2% both at panicle emergence and 15 days after panicle emergence (5.91 % disease index). Whereas, the highest disease severity (31.05 %) was noticed in control.

Among sixteen treatments, mean yield has ranged from 41.05 to 53.76 q ha^{-1}, whereas highest yield recorded was 53.76 q ha^{-1}in tebuconazole50 % + trifloxystrobin 25% 75 WG @ 0.04% at panicle emergence and after 15 days of panicle emergence followed by 51.87 q ha^{-1}in tebunconazole50 % + ttrifloxystrobin 25% 75 WG @ 0.04% at panicle emergence and 50.65 q ha^{-1} wasobserved in tebunconazole50 % + ttrifloxystrobin 25% 75 WG @ 0.04% at 15 days after panicle. Lower yield was recorded in control (41.05 qha^{-1}).

Among different treatments, the mean incremental benefit to cost ratio ranged from 1:2.59 to 1:10.09. The incremental benefit to cost ratio of 1: 10.09 has observed in tebunconazole 50 % + trifloxystrobin 25% 75 WG @ 0.04% at panicle emergence and folloed by 1:9.58 in hexaconazole 5% EC + captan 70% WP @ 0.2% at panicle emergence and 1:9.52 in propiconazole 25 EC @ 0.1% at panicle emergence. Whereas, least incremental benefit to cost ratio of 1:3.73 was recorded in mancozeb 75% WP @ 0.2% at 15 days after panicle emergence and 1:2.59 in *Pseuedomonas fluorescens* @ 0.5 % at 15 days after panicle emergence.

The results (Table 4.19, Fig.4.22) revealed that among different treatments, spray of tebunconazole 50 % + trifloxystrobin 25% 75 WG @ 0.04% (T_6) spray at panicle emergence stage was significantly better over other treatments (T_4 - 4.51 per cent disease index, grain yield of 51.87 q ha^{-1} with incremental benefit to cost ratio of 1 : 10.09) followed by treatments including spray of hexaconazole 5% EC + captan 70 % WP @ 0.2% at panicle emergence (T_7- 6.57 per cent disease incidence, grian yield of 49.95 q $ha^{-1}$with incremental benefit to cost ratio of 1 : 9.58) after T_1- propiconazole @ 0.1% at panicle emergence (T_1- 9.01 per cent disease index, grain yield of 47.85 q ha^{-1} with incremental benefit cost ratio of 1:9.52).

Table 4.19. Management of grain discolouration in rice through chemicals and bio–fungicides during *Kharif* 2018 at Yalandur taluk, Chamarajanagara

Treatments	Percent disease index	Yield (q/ha)	Incremental Benefit Cost Ratio (IBCR)
T_1- Propiconazole @ 0.1% at panicle emergence	9.01 (17.47)	47.85	1:9.52
T_2- Propiconazole @ 0.1% at 15 days after panicle emergence	10.02 (18.44)	46.32	1:7.37
T_3- $T_1 + T_2$	7.01 (15.35)	49.55	1:5.95
T_4- Tebuconazole 50 %+trifloxystrobin 25% 75\WG0.04 % at panicle emergence	4.51 (12.26)	51.87	1:10.09
T_5- Tebunconazole 50 %+Trifluoxystrobin 25% 75 WG 0.04 % at 15 days after panicle emergence	6.51 (14.78)	50.65	1:8.96
T_6- $T_4 + T_5$	3.98(11.51)	53.76	1:5.93
T_7- Hexaconazole 5% EC + captan 70 % WP @ 0.2% at panicle emergence	6.57(14.97)	49.95	1:9.58
T_8- Hexaconazole 5% EC + captan 70 % WP@ 0.2% at 15 days after panicle emergence	8.79 (17.25)	48. 62	1:8.15
T_9- $T_7 + T_8$	5.91 (14.07)	50.06	1:4.85
T_{10}- Mancozeb @ 0.2% at panicle emergence	14.95 (22.75)	44.06	1:7.02
T_{11}- Mancozeb @ 0.2% at 15 days after panicle emergence	17.91 (25.04)	42.65	1:3.73
T_{12}- $T_{10} + T_{11}$	13.49 (21.55)	45.01	1:4.62
T_{13}- *Pseudomonas fluorescens* @ 0.5 % at panicle emergence	18.86 (25.75)	42.45	1:4.90
T_{14}- *Pseudomonas fluorescens* @ 0.5 % at 15 days after panicle emergence	21.09 (27.34)	41.79	1:2.59
T_{15}- $T_{13} + T_{14}$	17.99 (25.10)	42.85	1:3.15
T_{16}- Control	31.05 (33.86)	41.05	-
S EM +_	0.42	0.22	-
CD @ 5 %	1.21	0.32	-
CV (%)	3.68	0.69	-
SEd	0.59	0.68	-

(*Values in parenthesis are arc sine transformed value)

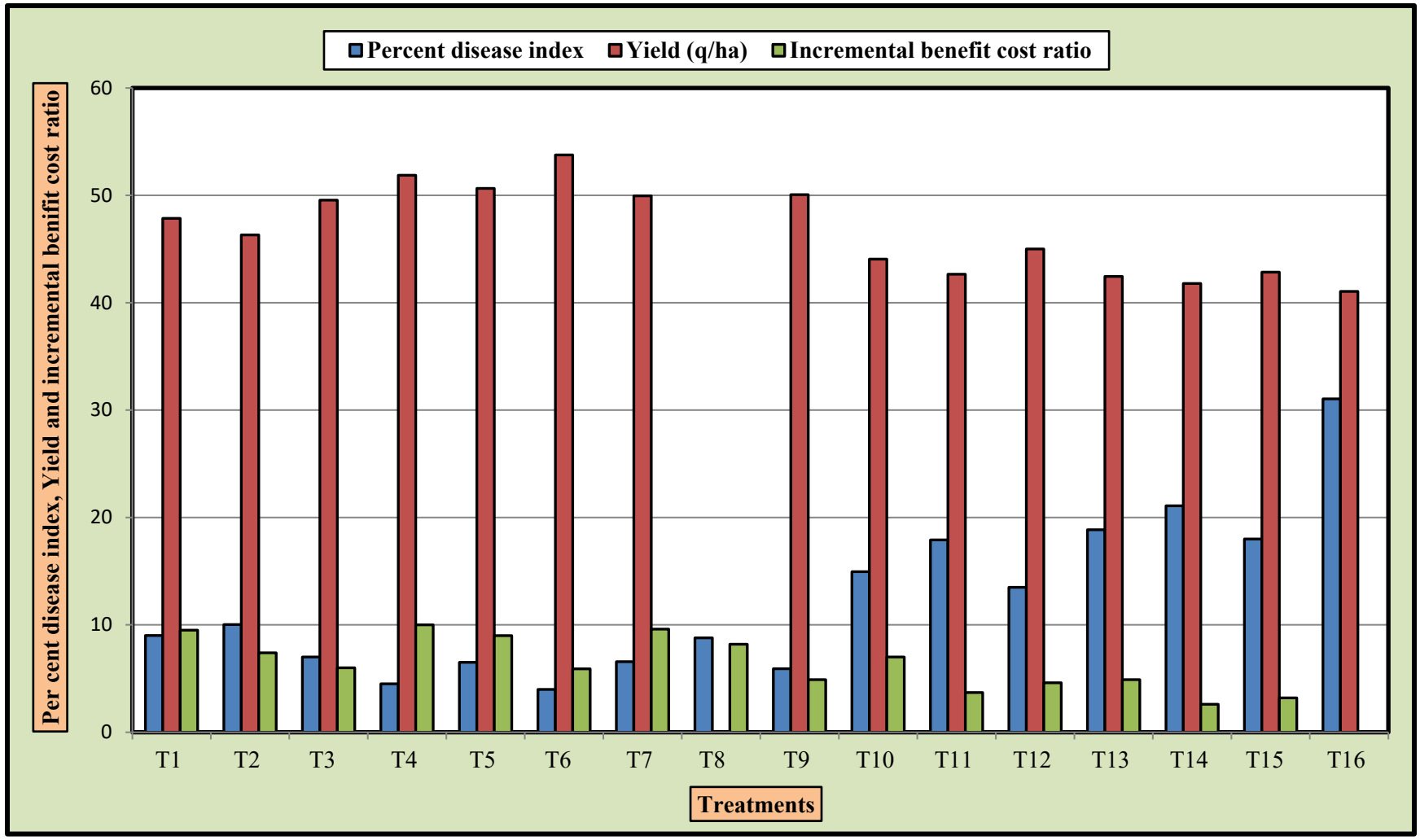


Fig.4.22. Management of grain discolouration in rice through chemicals and bio-fungicides during *Kharif* 2018 at Yalandur taluk, Chamarajanagara

Pooled data of *Kharif* 2017 and 2018 revealed that among all tested treatments, tebuconazole50 % + trifloxystrobin 25% 75 WG @ 0.04% sprayed at panicle emergence was significantly superior over other treatments with the intensity of 4.65, yield 53.09 q/ha and incremental benefit cost ratio of 1: 11.47 followed by hexaconazole 5% EC + captan 70% WP @ 0.2% spray at panicle emergence sprayed plots with severity of 6.51, grain yield of 50.75 q ha^{-1} with incremental benefit cost ratio was 1: 10.77 and propiconazole 25% EC @ 0.1% spray at panicle emergence with disease severity of 8.78, grain yield of 48.30 q ha^{-1} with incremental benefit cost ratio was 1: 10.57. Whereas, highest per cent disease index of 31.52 and grain yield 40.79 q ha^{-1} were noticed in control plot (Table 4.20, Fig. 4.23 and Plate11).

The new molecule of fungicide tebuconazole 50 % + trifloxystrobin 25% 75 WG @ 0.04% is a broad spectrum of systemic fungicide having both protective and curative action against rice grain discoloration disease and its very effective in managing the disease at panicle initiation stage itself besides improving the quality of grain and yield level. This fungicide is also having two molecules *viz.*, tebuconazole belongs to triazole group containg dimethylase inhibitor (DMI) which interferes with process of building fungal cell wall structure and inhibits growth and reproduction of the fungus. trifloxystrobin dispruts respiration of plant pathogenic fungi. So, this new molecule was very effective against grain discolouration compare to other fungicides and bio-control agent. Similiarly the systemic fungicides propiconazole @ 0.1% and hexaconazole 5% EC were also very effective against rice grain discolouraion where belongs to trizole group of fungicide. These results are in acceptance with Lore *et al*., (2007) who reported that the propiconozole was highly effective followed by hexaconazole and carbendazim against rice grain discolouration. Similar results were reported by many workers. Fungicides *viz.*, carbendazim (0.1%), carbendazim + mancozeb (0.15%) (Anwar and Bhat, 2008) and hexaconazole (0.2%) (Bag *et al*., 2010; Bag and Biswas, 2010) were effective in reducing the grain discolouration and these findings also supports our results.

Table 4.20. Management of grain discolouration in rice through chemicals and bio-fungicides during *Kharif* 2017 and *Kharif* 2018 (Mean) at Yalandur taluk, Chamarajanagara

Treatments	Percent disease index	Yield (q /ha)	Incremental Benefit Cost Ratio (IBCR)
T_1- Propiconazole @ 0.1% at panicle emergence	8.78 (17.24)	48.30	1: 10.57
T_2- Propiconazole @ 0.1% at 15 days after panicle emergence	9.89 (18.33)	46.82	1: 8.43
T_3- $T_1 + T_2$	7.43 (15.82)	50.05	1: 6.47
T_4- Tebuconazole 50 %+ trifloxystrobin 25% 75 \ WG0.04 % at panicle emergence	4.65 (13.40)	53.09	1: 11.47
T_5- Tebuconazole 50 %+ trifloxystrobin 25% 75 WG 0.04 % at 15 days after panicle emergence	6.58 (14.86)	51.65	1: 10.17
T_6- $T_4 + T_5$	3.92 (11.42)	55.04	1: 6.64
T_7- Hexaconazole 5% EC + captan 70 % WP @ 0.2% at panicle emergence	6.51 (14.78)	50.75	1: 10.77
T_8- Hexaconazole 5% EC + Captan 70 % WP@ 0.2% at 15 days after panicle emergence	8.67 (17.12)	48.92	1: 8.74
T_9- $T_7 + T_8$	5.93 (14.09)	51.52	1: 5.77
T_{10}- Mancozeb @ 0.2% at panicle emergence	15.41 (23.11)	43.91	1: 7.26
T_{11}- Mancozeb @ 0.2% at 15 days after panicle emergence	17.83 (24.98)	42.65	1: 4.14
T_{12}- $T_{10} + T_{11}$	13.73 (21.75)	45.44	1: 5.41
T_{13}- *Pseudomonas fluorescens* @ 0.5 % at panicle emergence	19.36 (26.10)	42.25	1: 5.09
T_{14}- *Pseudomonas fluorescens* @ 0.5 % at 15 days after panicle emergence	21.54 (27.65)	41.49	1: 2.53
T_{15}- $T_{13} + T_{14}$	18.02 (25.12)	43.20	1: 3.33
T_{16}- Control	31.52 (34.15)	40.79	-
S EM ±	0.43	0.69	-
CD @ 5 %	1.23	0.98	-
CV (%)	3.69	2.13	-
SEd	0.60	2.09	--

(*Values in parenthesis are arc sine transformed value)

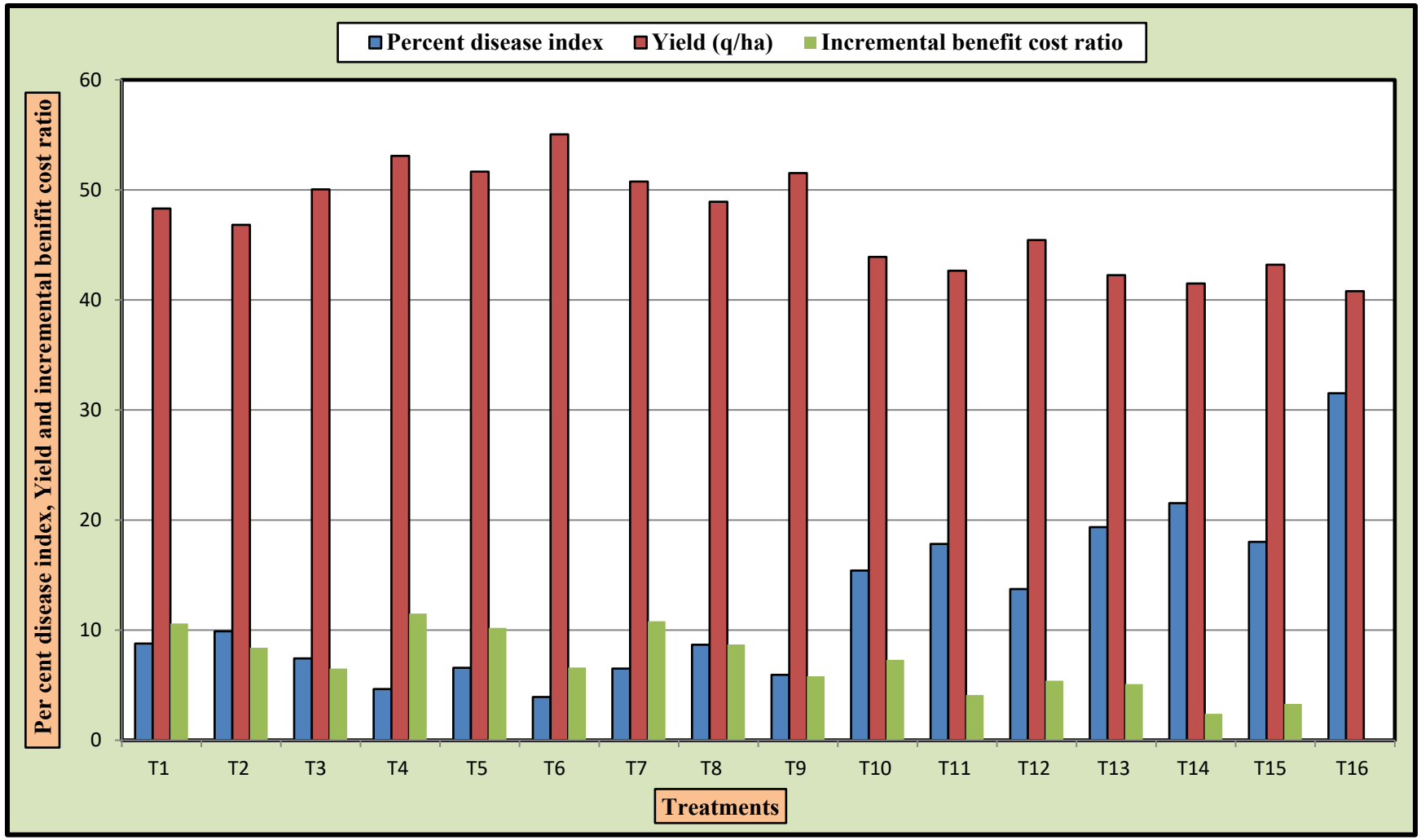


Fig.4.23. Management of grain discolouration in rice through chemicals and bio -fungicides during *Kharif* 2017 and *Kharif* 2018 (Average) at Yalandur taluk, Chamarajanagara

A. T_4-Tebunconazole50 % + Trifluoxystrobin 25% 75 WG 0.04 % at panicle emergence

B. T_{16} – Control

Plate 10. Management of rice grain discolouration through fungicides and bio-fungicide

V SUMMARY AND CONCLUSION

In earlier days, the grain discolouration of rice was considered as a minor disease, but now it is gaining more importance. The discolouration of rice grain is also known as "glume discolouration" or "dirty panicle*"* and it has been spread all over the world, particularly where rice crop is being cultivated extensively. But, the extent damage of grain discolouration varies with varieties, growing seasons and local weather parameters *viz.* moisture, rainfall, relative humidity, congenial temperature and cloudy weather occurred particularly from panicle initiation to maturity stage. These conditions were most favorable for infection on grains by the various pathogens in turn it results in reduction in germination, seedling vigour and quality of grains. Now, it is one of economically important disease causing 5 to 25 per cent of yield loss but has given lesser emphasis on research work. Therefore, in this study more focus has been given on various aspects of research investigations on grain discolouration in rice *viz*., survey and surveillance of grain discolouration in different rice ecosystems of Karnataka, studies on isolation of pathogens colonized with discoloured grains, screening rice genotypes of rice for reaction to grain discolouration, studies on biochemical aspects and management of grain discolouration in rice using fungicides and bio-agents.

Surveillance study was conducted during *Kharif* 2017 and 2018 in three major rice growing ecosystems *viz*., Hilly upland, Costal and irrigated areas of Kabini, Kaveri, Tunga, Bhadra, Upper Krishna and Tungabhadra. The healthy and discoloured rice grain samples were gathered from two hundred and seven rice fields covering sixty-nine villages, twenty three taluks across fifteen districts of Karnataka. Further, recorded the severity and disease incidence of healthy and discoloured grain samples by using standard evaluation system scale 0 to 9. Among three ecosystem surveyed during *Kharif* 2017 and 2018, the highest average incidence of disease (15.21%) and severity (13.79%) was observed in Hilly ecosystem followed in Coastal ecosystem (14.66% incidence and 13.35% severity), Tungabhadra and Upper Krishna Project (12.42% incidence and severity of 11.85%), Kabini and Kaveri (12.19% incidence and 11.43% severity) and Tunga and Bhadra (11.54% incidence and 10.62% severity). The higher incidence of

grain discolouration was noticed in long and medium duration genotypes with fine quality rice than the short duration genotypes.

Twenty-two discoloured grain samples of different rice genotypes were subjected to isolation by various methods (blotter, agar plate and paper towel). Later, identification of the associated fungal mycoflora with discoloured grains was carried out separately.

In blotter paper method, the mycoflora commonly colonized with the grain samples *viz.*, *Helminthosporium* sp., *Curvularia* sp., *Alternaria* sp., *Aspergillus* sp., *Fusarium* sp., *Cladosporium* sp., *Phoma* sp. and *Magnaporthe oryzae.* The diversity of mycoflora was recorded highest in BPT-5204 followed in Jyothi, Jayakrishna, Super Aman, MTU-1001, RNR-15048, Nellur Sona, Kaveri Sona, IR-64, BR-2655, Jayashree, Gangavathi Sona, MTU-1010, KRH-4, Intan and Kaje Jaya and least in varieties like Jaya, Thanu, KMP-105, Abhilash and Rasi.

In agar plate method, the mycoflora detected were *Helminthosporium*sp., *Curvularia* sp., *Alternaria* sp., *Aspergillus* sp., *Fusarium* sp., *Trichoderma* sp. and *Rhizopus sp.*Whereas, the mycofloral diversity was highest in Jyothi (6) on par with BPT-5204 (6) followed by Super Aman (5), Jayashree (5), Intan (5), Jayakrishna (4), Gangavathi Sona (4), MTU -1010 (4), KMP-105 (4), RNR-15048 (4), Nellur Sona (4), Kaveri Sona (4), IR-64 (3), Jaya (3), Thanu (3), MTU-1010 (3), KRH-4 (3), KajeJaya (3) and Rasi (3) and least in varieties like BR-2655 (2), Abhilash (2) and Hemavati (2)

In paper towel method, the presence of maximum diversity of mycoflora was found in Jyothi with six mycofloral species (*Fusarium* sp*., Aspergillus* sp., *Curvularia* sp., *Alternaria* sp., *Helminthosporium* sp. and *Rhizopus* sp.) whereas, *Aspergillus* sp. and *Helminthosporium* sp. were only observed in BR-2655, *Curvularia* sp., and *Helminthosporium* sp. observed in Jaya, whereas *Alternaria* sp. and *Helminthosporium* sp. noticed in Kaje Jaya and Rasi, respectively.

Under natural condition, a set of thirty-eight rice genotypes were screened, of which, none of them was found immune and resistant. However, five genotypes like Jaya, BR-2655, Rajamudi, KCP-1 and Ratnachudi were found moderately resistant. Twenty

one genotypes *viz.,* KMP-153, Rasi, IR-64, CTH-1, Mandya Sona-2, MTU-1010, Raksha, KMP-128, IR-30864, Jaya X ASD MSN-100, KMP-200, GVT-7, GVT-4, KRH-4, MTU-1001, Tellahamsa, MSN-99, KMP-149, Jyoti X BR-2655 and HR-12 were showed moderately susceptible reaction. The twelve genotypes were susceptible *viz.* BPT- 5204*,* KMP-175, KMP-201, Jyothi, JGL-1798, Basumati-270, Mandy Sona-1, Gangavathi Sona, RNR-15048, Mandya Vijaya, CTH-3 and Thanu.

Total phenol content per gram of healthy and discoloured grains of all rice genotypes was significantly different. In discoloured rice grains, phenol content varied from 44.86 to 76.87 mg/g and in healthy grains values ranged from 39.74 to 64.10 mg/g. Total phenol content showed variation in moderately resistant, moderately susceptible and susceptible genotypes. Whereas, the highest total phenol content was recorded in moderately resistant genotypes *viz.*, BR-2655 (64.10 mg/g in healthy, 76.87 mg/g in diseased samples) followed by Jaya (63.76 mg /g in healthy and 75.09 mg/g in diseased samples) as compared to moderately susceptible and susceptible rice genotypes.

Total, reducing and non reducing sugar content in healthy and discoloured grains among rice varieties was statistically significant. Among the healthy grains, total sugar content ranged from 20.65 to 28.82 mg/g, whereas in discoloured grains, it ranged from 22.87 to 34.82 mg/g. The reducing sugar content was ranged from 13.68 to 29.55 mg/g in diseased samples and 12.67 to 24.43 mg/g in healthy samples of all tested rice genotypes.

All the sixteen treatments (fungicides and bio-fungicide) imposed for the management of grain discolouration of rice has recorded significant reduction of disease incidence over untreated check. Tebuconazole 50 % + trifloxystrobin 25% 75 WG @ 0.04% sprayed at panicle emergence significantly superior to other treatments with disease severity of 4.65%, grain yield of 53.09 q ha^{-1} with incremental benefit cost ratio of 1: 11.47 followed by hexaconazole 5% EC + captan 70% WP @ 0.2% at panicle emergence sprayed plots with disease intensity of 6.51%, grain yield of 50.75 q ha^{-1} with incremental benefit cost ratio of 1: 10.77 and propiconazole 25% EC @ 0.1% sprayed at panicle emergence recorded disease severity of 8.78%, grain yield of 48.30 q ha^{-1} with incremental benefit cost ratio of 1: 10.57, whereas, maximum disease severity of 31.52 % and grain yield of 40.79 q ha^{-1} were noticed in control plot.

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Screening of Rice (*Oryza sativa* L.) Genotypes against Grain Discoloration Disease

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Two years, *kharif* 2017 and 2018, screening of rice genotypes against grain discoloration under field conditions in Yalandur taluk, Chamarajanagara district revealed that five genotypes viz., *viz.,* BR-2655, Jaya, KCP-1, Rajamudi and Ratnachudi were found moderately resistant. Out of thirty-eight rice genotypes screened, none of the them were found immune or resistant but twenty-one genotypes showed moderate susceptibility and twelve genotypes were susceptibility, The identified moderately resistant genotypes could be used in the disease resistant breeding programme as grain discoloration is considered one of the most important threats to paddy cultivation in Kabini, Kaveri, Thunga, Bhadra, Hilly upland and Coastal areas.

Introduction

Rice (*Oryza sativa* L.) is the most important crop of the world both in terms of area (433.38 m ha) and production (481.54 m t) (Anon., 2016). One out of every three people depends on rice for more than half of their daily diet. Rice is most important staple food in Asia, where 60 per cent world population lives and accounts between 35 -60 per cent of the caloric intake of three billion Asians. In India rice is grown in 43.86 m ha, the production level was 104.80 mt and the productivity of 2404 kg/ ha (Anon., 2016). In Karnataka, rice is also extensively cultivated both in *kharif* and rabi seasons. Total area under rice in Karnataka is 1.42 mha with a production of 3.6 mt accounting for a productivity of 2.62 t per ha (Anon., 2016**).** This low productivity is attributed due to abiotic and biotic stresses leading to heavy crop losses. Rice crop is prone to attack by several diseases to a much larger extent than any other cereal crops. Rice crop suffers from many diseases like blast, sheath blight, sheath rot, bacterial blight, false smut, grain discoloration, udabatta and tungro. Throughout the world these diseases have drawn much attention and consequently, these diseases have been intensively studied. However, other diseases on which sufficient stress in not yet devoted are generally

considered as "minor disease". But for the past 5-10 years such diseases problems have come in to light due to heavy crop losses mainly in costal tracts of India, consisting the states namely Andhra Pradesh, Tamil Nadu, Karnataka, West Bengal, Odisha and parts of Bihar.

Grain discoloration was considered to be a minor disease and is now receiving more attention in tropical rice growing areas. The disease is distributed throughout Asia, Africa and America. It is a complex disease due to infection by pathogens on the glume, kernals or both. In Karnataka, it is considered as one of the most important threats to paddy cultivation in Kabini, Kaveri, Thunga, Bhadra, Tungabhadra Hilly upland and Coastal areas. Its intensity varies according to seasons and localities factors such as lodging, frequent rain, high relative humidity and cloudy weather, prevailing particularly from booting to maturity influence the development of grain discoloration.

The main cause of grain discoloration is due to various pathogens, especially species of fungi viz., *Curvularia, Drechslera, Sarocladium, Fusarium* etc. (Bag, 2007; Sachin and Agarwal, 1995). Grain discoloration results in seedling mortality and reduction in germination and seedling vigour (Bag, 2007), causing significant yield loss. Thus, the pathogens causing grain discoloration have direct influence on both quantity and quality of seeds. Discoloration results in poor quality of grain or seed and an important degrading factor. In such seeds disorders may indicate the presence of seed borne pathogen (Padmanabhan, 1974). In the present context, the development variety looks like an apt choice in the crop improvement programme and is an integral part of Integrated Disease Management (IDM) programmes. Further, it will go a long way in avoiding fungicidal toxicity likely to occur due to chemical spray.

Materials and Methods

Thirty-eight rice genotypes were collected from Zonal Agricultural Research Station, V.C. Farm, Mandya for screening rice genotypes against grain discoloration. The experiments were conducted in the farmer's field of Yalandur taluk, Chamarajanagara district during *kharif* 2017 and 2018. The experiment was laid out in Randomized Black Design with two replications in a plot size of 3 m^2 and spacing of 20 x 10 cm. Fertilizers applied at the rate of 100:50:50 kg N, P_2O_5, K_2O /ha. N and P_2O_5 were applied in the form of urea and single super phosphate and potash in the form of muriate of potash. At maturity five ear-heads from each entry were collected and threshed grains were assessed for percentage discoloration by counting the number of healthy and discoloured grains with in the sample.The per cent discoloration was calculated by using the following formulae:

$$\text{\% Discoloured grains (number based)} = \frac{\text{Number of discoloured grains}}{\text{Total number of grains}} \text{ X } 100$$

Later, based on 0 to 9 disease rating scale, the rice genotypes were grouped in to immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible (Anon., 2013) (Table 1).

Results and Discussion

A total of thirty-eight rice genotypes of short, medium and long duration varieties/ hybrid were screened against grain discoloration during *Kharif*2017 and 2018 in the farmer's

field of Yalandur taluk, Chamarajanagara district. The data is presented in the (Table 2 and Fig. 1a - 1c) revealed that, during the *Kharif* season of 2017, the lowest of 4.80 per cent discoloration was noticed in Ratnachudi and the highest of 48 per cent in Jyoti (Table 2 and Fig. 1a). Similarly, in *Kharif* 2018, the lowest of 4.85 per cent discoloration was noticed in KCP-1 and the highest of 49 per cent in Mandya Vijaya (Table 2 and Fig. 1b). The average of two seasons indicated that discoloration varied from 4.75 (Jaya) to 47.75 (Mandya Vijaya) per cent (Table 2 and Fig. 1c). The present results are in agreement with Negiand Das (2003).

Out of thirty eight genotypes evaluated, none was found to be immune and resistant against grain discoloration. However, five genotypes *viz.,* BR-2655, Jaya, KCP-1, Rajamudi, and Ratnachudi were found moderately resistant and twenty one genotypes *viz.,* Rasi, KMP-153, IR-64, Mandya sona-2, Raksha, KMP-128, Jaya X ASD, MTU-1010, IR-38064,CTH-1, MSN-100, KMP-200,, GVT-7, GVT-4, KRH-4, MTU-1001, Tellahamsa, MSN-99, KMP-149, Jyoti X BR-2655 and HR-12, twelve genotypes were susceptible *viz.,* KMP-201, KMP-175, BPT-5204, Jyoti, Basumati-270, JGL-1798, MS-1, Gangavatisona-VCF, Mandya Vijaya, Thanu, RNR-58048, CTH-3 showed moderate susceptibility reaction and none of the genotypes showed highly susceptible reaction and which are represented in (Table 3). The present results are in agreement with findings of Saifulla (1993), Bhimanagouda (2012) Divya (2015) and Varshashikhara (2018).

These conditions also increased the duration of flower opening which predisposed the crop to grain discoloration. The identified moderate resistant genotypes be recommended for cultivation in endemic areas and may be used as source of resistant in the breeding programme in crop improvement. This helps to solve the problem of loss due to this disease and also to avoid the chemical protection/ pollution.

Table.1 Scale description for scoring grain discoloration disease of rice

Disease Score (0 –9)	Description	Response
0	No symptom of discoloration	Immune
1	Less than 1% discoloration	Resistant
3	1 to 5 % discoloration	Moderately Resistant
5	6 to 25 % discoloration	Moderately Susceptible
7	26 to 50 % discoloration	Susceptible
9	51 % to 100% discoloration	Highly Susceptible

Table.2 Screening of short, medium and long duration varieties and hybrid against rice grain discoloration during *Kharif* 2017-8 and 2018-19 at Chamarajanagara

Treatments	Per cent discoloration		
Variety	*Kharif* 2017	*Kharif*2018	Pooled
T_1 Rasi	9.08 (17.50)	5.08 (12.94)	**7.08 (15.39)***
T_2 KMP-153	5.00 (12.92)	8.00 (16.31)	**6.5 (14.72)**
T_3 IR-64	21.00 (27.25)	19.50 (26.19)	**20.25 (26.74)**
T_4 Mandya sona-2	16.00 (23.56)	18.00 (25.07)	**17.00 (24.32)**
T_5 Raksha	14.50 (22.25)	11.50 (19.77)	**13.00 (21.09)**
T_6 KMP-201	35.00 (36.26)	29.00 (32.57)	**32.00 (34.44)**
T_7 KMP-128	16.80 (24.16)	12.60 (20.74)	**14.70 (22.50)**
T_8 KMP-175	36.00 36.87)	31.60 (34.18)	**33.80 (35.55)**
T_9 BR-2655	4.50 (12.18)	5.00 (12.86)	**4.75 (12.52)**
T_{10} Jaya X ASD	8.00 (16.31)	7.00 (15.26)	**7.50 (15.84)**
T_{11} MTU -1010	21.66 (27.73)	18.00 (25.07)	**19.83 (26.44)**
T_{12} BPT-5204	42.14 (40.47)	39.40 (38.88)	**40.77 (39.67)**
T_{13} Jyoti	48.00 (43.85)	45.00 (42.18)	**46.50 (42.99)**
T_{14} Basumati-270	41.50 (40.10)	39.00 (38.64)	**40.25 (39.37)**
T_{15} IR-38064	19.00 (25.81)	23.00 (28.64)	**21.00 (27.25)**
T_{16} Jyoti X BR-2655	18.00 (25.10)	24.00 (29.31)	**21.00 (20.51)**
T_{17} CTH-1	9.75 (18.16)	14.80 (22.58)	**12.27 (28.82)**
T_{18} HR-12	24.53 (29.67)	22.00 (27.95)	**23.26 (24.71)**
T_{19} MSN100	16.00 (23.57)	19.00 (25.81)	**17.50 (21.08)**
T_{20} KMP-200	12.00 (20.20)	14.00 (21.92)	**13.00 (30.63)**
T_{21} CTH-3	24.00 (29.33)	28.00 (31.93)	**26.00 (29.36)**
T_{22} GVT-7	20.55 (26.93)	27.58 (31.66)	**24.06 (23.54)**
T_{23} GVT-4	14.00 (21.92)	18.00 (25.07)	**16.00 (36.33)**
T_{24} JGL-1798	31.80 (34.32)	38.4 (38.29)	**35.10 (27.22)**
T_{25} KRH-4	18.00 (25.07)	24.00 (29.31)	**21.00 (31.07)**
T_{26} MS-1	25.88 (30.56)	27.50 (31.61)	**26.69 (12.65)**
T_{27} Jaya	4.80 (12.60)	4.88 (12.70)	**4.84 (33.82)**
T_{28} Gangavatisona-VCF	34.00 (35.66)	27.00 (31.29)	**31.00 (43.71)**
T_{29} Mandyavijaya	46.50 (42.99)	49.00 (44.43)	**47.75 (12.75)**
T_{30} KCP-1	5.00 (12.86)	4.85 (12.67)	**4.92 (20.90)**
T_{31} MTU-1001	9.00 (17.36)	17.50 (24.68)	**12.75 (28.98)**
T_{32} Tellahamsa	19.00 (25.81)	28.00 (31.93)	**23.50 (12.89)**
T_{33} Rajamudi	5.08 (13.01)	4.88 (12.70)	**4.98 (12.89)**
T_{34} Thanu	30.00 (33.20)	35.50 (36.56)	**32.75 (34.90)**
T_{35} Ratnachudi	4.80 (12.59)	4.90 (12.71)	**4.85 (12.65)**
T_{36} RNR-58048	24.00 (29.31)	29.00 (32.57)	**26.50 (30.95)**
T_{37} MSN-99	12.00 (20.20)	10.00 (18.35)	**11.00 (19.30)**
T_{38} KMP-149	10.80 (19.15)	9.90 (18.25)	**10.35 (18.71)**
S.Em +_	1.30	1.40	**1.32**
C.V.	7.32	7.61	**7.22**
C.D. @5%	**3.77**	**4.02**	**3.78**

*(Figures in parenthesis are arc sine transformed values)

Table.3 Reaction of rice genotypes against rice grain discoloration

Disease rating scale	Response	No. of entries	Name of varieties / Hybrid varieties/ Germplasm
0	Immune	Nil	Nil
1	Resistant	Nil	Nil
3	Moderately Resistant	5	BR-2655, Jaya, KCP-1, Rajamudi, and Ratnachudi
5	Moderately susceptible	21	Rasi, KMP-153, IR-64, Mandya sona-2, Raksha, KMP-128, Jaya X ASD, MTU-1010, IR-38064,CTH-1, MSN-100, KMP-200,, GVT-7, GVT-4, KRH-4, MTU-1001, Tellahamsa, MSN-99, KMP-149, Jyoti X BR-2655, HR-12
7	Susceptible	12	KMP-201, KMP-175, BPT-5204, Jyoti, Basumati-270, JGL-1798, MS-1, Gangavatisona-VCF, Mandyavijaya, Thanu, RNR-58048, CTH-3
9	Highly susceptible	Nil	Nil

Fig.1a Screening of rice varieties/ hybrids against grain discoloration during *Kharif* 2017

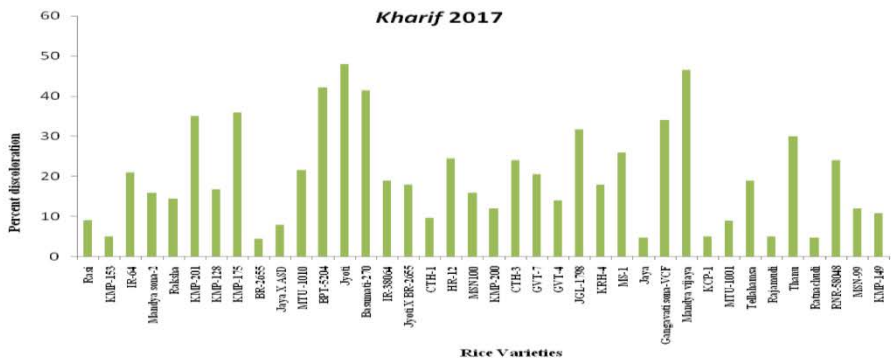


Fig.1b Screening of rice varieties / hybrids against grain discoloration during *Kharif* 2018

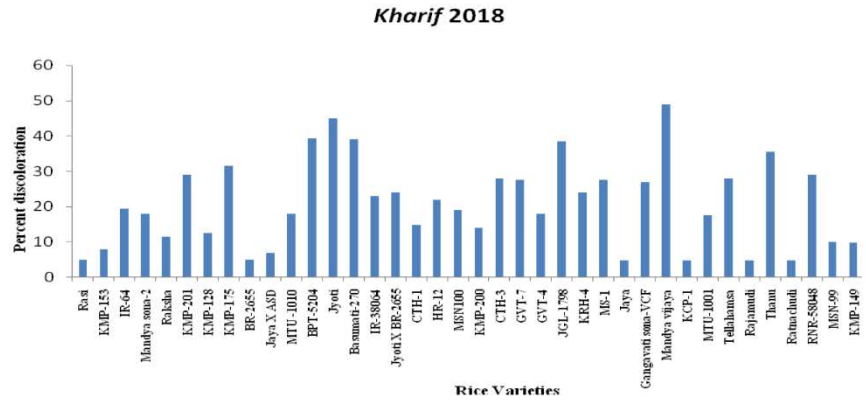
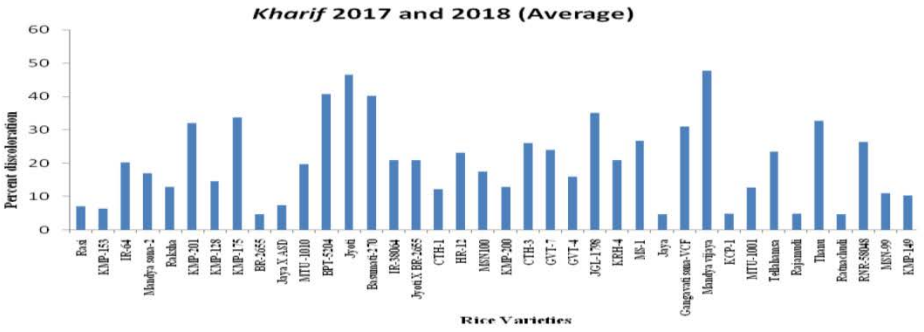


Fig.1c Screening of rice varieties / hybrids against grain discoloration during *Kharif* 2017and k*harif* 2018 (Average)



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Status and Distribution of Rice Grain Discolouration in Different Ecosystems in Karnataka, India

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A B S T R A C T

A roving survey was conducted during *Kharif* 2017 and 2018 in five major rice growing ecosystems *viz.,* Kabini and Kaveri, Hilly upland, Thungabhadra and Upper Krishna, Thunga and Bhadra and Coastal belts to know the incidence and severity of grain discolouration in Karnataka. Grain discolouration was recorded in all the samples collected from major rice growing ecosystems. The mean per cent grain discolouration and mean per cent disease index during *Kharif* 2017 was 12.87 and 12.04 and *Kharif* 2018 was 13.24 and 12.27 respectively. Both the years, the maximum percent incidence of disease 14.95 and 15.47 and per cent disease index 13.64 and 13.94 respectively was observed in Hilly upland followed by costal belt 14.33 and 15.00 and 13.04 and 13.67 respectively, whereas the least incidence 11.23 and 11.85 and severity 10.22 and11.03 was noticed in Thunga and Bhadra ecosystem.

Introduction

India has a long history of rice cultivation. Globally, it stands first in rice area (42.41 million ha) and second in rice production (166.5 million tonnes) (FAO, 2018) after China. It contributes 21.6 per cent to global rice production. Within the country, rice occupies one-quarter of total cropped area, contributes about 40 to 43 per cent of total food grain production and continues to play a vital role in the national food and livelihood security system.

Total area under rice in Karnataka is 1.42 million ha with a production of 3.6 million tones accounting a productivity of 2.62 tonnes per ha. The grain yield per unit area is reducing due to various factors, among which diseases and abiotic stresses are major causes

for low yield. Rice crop is attacked by more than 76 fungi, bacteria, viruses and mycoplasma like organism causing various diseases in the field. Discolouration has been observed in almost all part of the world wherever rice grown. It was earlier considered to be a minor disease but now gaining more importance due to its severity in tropical rice growing areas.

The disease is distributed throughout Asia, Africa and America. In many regions of India, the early and medium duration rice cultivars grown particularly in wet seasons are generally exposed to high humidity and warm environmental conditions during flowering and post flowering stages which significantly favours the disease incidence.

The fungi reported to be associated with discolouration of grains are *Curvularia lunata* (highest 35.30% in Tungabhadra Project-TBP and Upper Krishna Project-UKP areas of North Eastern Karnataka), *Alternaria alternate, Fusarium moniliforme, Bipolaris oryzae*, *Alternaria padwickii, Pyricularia oryzae, Fusarium graminareum, Nigrospora oryzae, Epicoccum nigrum, Phoma sorghina, Dichotomophthoropsis nymphacearum* and *Heterosporium echinunulatum* etc. (Sumangala and Patil, 2009a).

Rice yield loss due to pests and diseases have been noticed more seriously than ever before. Grain discolouration is considered as "One of the most important threats to rice cultivation" in Karnataka.

The incidence of disease and associated organisms confined to rice crop, it varies with environmental conditions *viz.,* and moisture, temperature, and relative humidity were prevailing in the location. These factors vary with one ecosystem to another ecosystem. In Karnataka, the rice crop is being cultivated in different ecosystem *viz.,* Kabini and Kaveri, Hilly, Tungabhadra and Krishna, Thunga and Bhadra, and Costal. To know the incidence and severity of grain discolouration in different ecosystem the roving survey has been carried out during *Kharif* 2017 and *Kharif* 2018.

Materials and Methods

Seed samples were collected through roving surveys conducted during *Kharif* 2017 and *Kharif* 2018 from farmer's fields of Mysore, Mandya, Chamarajanagara, Kodagu, Uttarkannada, Yadagir, Raichur, Koppal, Bellary, Shivamogga, Chikkamagaluru, Davanagere and Dakshina Kannada districts representing five rice ecosystem.

In each district, one or two taluks, in each taluk, three village and in each village, three plots were surveyed and are listed in the Table 1.Randomy 10 representative panicles from different fields at each location comprising of cultivars were collected, labeled and packed in polyethylene bags and were stored at room temperature (30 ± 2 ^{0}C) for further investigation.

The disease was scored by using 0-9 scale given by IRRI, 2013.

Score	Description
0	No symptom of discolouration
1	Less than 1% discolouration
3	1 to 5 % discolouration
5	6 to 25 % discolouration
7	26 to 50 % discolouration
9	51 % to 100% discolouration

Per cent disease index was worked out by using the formula

$$PDI = \frac{\text{Sum of individual diseased grain ratings}}{\text{No. of grains assessed}} \times \frac{100}{\text{Maximum grade}}$$

Grain discolouration (%) was calculated by using the formula,

$$= \frac{\text{No. of panicles affected}}{\text{Total no. of panicles observed}} \times 100$$

Results and Discussion

Survey and surveillance studies on grain discolouration helps to identify the "hot spot" of grain discolouration disease in rice from five major rice growing ecosystems of Karnataka. The roving survey was conducted to assess incidence and severity of grain discolouration during *Kharif* 2017 and 2018 in different taluks of Mysuru, Mandya, Chamarajanagara, Kodagu, Uttara Kannada, Yadagir, Raichur, Koppal, Ballari, Shivamogga, Chikkamagaluru, Davanagere and Dakshina Kannada districts representing major five rice ecosystems *viz.*, Kabini and Kaveri, Hilly upland, Thungabhadra and Upper Krishna, Thunga, Bhadra and Coastal belts of Karnataka. The details of farmer's field surveyed are presented in Table 1 and 2 and were graded as healthy or discoloured grains for further examination.

During *Kharif* 2017, five major rice growing ecosystems surveyed, the incidence of grain discolouration and severity of disease was prevalent in all the five ecosystems with mean percent disease incidence ranged from 11.23 to 14.95 and mean per cent disease index ranged from 10.22 to 13.64, respectively (Table 1, 2, Fig.1). while the, maximum percent incidence of disease (14.95%) and per cent disease index (13.64%) was observed in hilly upland followed by Costal belt (14.33%) and (13.04%), whereas the least incidence (11.23%) and severity (10.22%) was noticed in Thunga and Bhadra ecosystems. The survey data are presented in (Table 1, 2, Fig.1). Among 13 districts surveyed across ecosystems, the incidence and severity of grain discolouration was observed in all districts. The mean per cent disease incidence ranged from 10.29 to 15.70 and mean per cent disease index ranged from 8.64 to14.56. The highest per cent grain discolouration was observed in Kodagu district (15.70%) followed by Dakshina Kannada district (14.44%) and least incidence was noticed in Davanagere district (10.29%).

While the disease severity was maximum in Kodagu district (14.56%) followed by Dakshina Kannada (13.49%) and least percent disease index (8.64%) was observed in Ballari district. The detailed data are presented in (Table 1,).

Out of 69 villages surveyed, highest incidence of disease was in Kankanadi village(17.33%) in Mangaluru taluk followed by in Mudbidari(16.00%) in Mangaluru taluk, Hudikeri village in taluk, Bashi village in Sirsi taluk, Madhuvinahalli village in Kollegal taluk, Devarahalli village in Maddur taluk and Basapattana village in Ballari taluk.

The least incidence Mallanayankanakatte village (8.00%) in Mandya taluk and Kondajji village in Harihara taluk, whereas highest per cent disease index (16.29%) in Hudikeri village in Ponnampet and Kankanadi village in Mangaluru taluk followed by (14.81%) in Mudbidari in Mangaluru taluk, Kumata village in Uttara Kannada, Basapattana village in Ballari taluk and Gorebal village in Sindhanoor taluk. The detailed data are presented in (Table 1)..

During *Kharif* 2018, The incidence of grain discolouration and severity of disease was prevalent in all five ecosystems with mean percent incidence ranged from 11.85 to 15.47 and mean per cent disease index ranged from 11.03 to 13.94, respectively (Table 1, 2, Fig.2). The highest percent incidence (15.47%) and per cent disease index (13.94%)

was observed in Hilly upland followed by Costal belt (15.00%) and (13.67%), whereas the least incidence (11.85%) and severity (11.03) was noticed in Thunga and Bhadra ecosystem. The data are presented in (Table 1, 2, Fig.2).

Totally thirteen districts surveyed, the incidence and severity of grain discolouration was observed in all districts. The mean per cent disease incidence ranged from 10.95 to 16.14 and mean per cent disease index ranged from 10.31 to14.56. The highest per cent discolouration (16.14%) was observed in Kodagu district followed by Dakshina Kannada district (15.23%) and least incidence was noticed in Davanagere district (10.95%).

While the disease severity was maximum in Dakshina Kannada district (14.56%) followed by Kodagu district (14.31%) and least percent disease index (10.31%) was observed in Davanagere district and data are presented in (Table 1,).

Out of 69 villages surveyed, highest incidence of disease(17.77%) was in Kankanadi village in Mangaluru taluk and Srimangala village in Ponnampet taluk followed by (16.00%) in Bashi village in Sirsi taluk, Gowdahalli village in Kollegal taluk, Kumata village in Uttara Kannada taluk, Suttur village in Mysuru taluk and Udupi village in Udupi taluk and least incidence in Kondajji village in Harihara taluk and highest per cent disease index (15.55%) in Udupi village in Udupi taluk followed by (14.81%) in Kundapur village in Udupi taluk, Kumata village in Uttara Kannada, Bashi village in Sirsi taluk and Guttiganur village in Ballari taluk and least percent disease index (10,31%) was observed in Agatahalli village in Pandavapur taluk and Avaraglla village in Davanagere taluk, and data are presented in (Table 1). The results from table 3 indicated that, grain discolouration of rice was prevalent in all five ecosystems surveyed which include 207 fields form 69 villages of 23 taluks from fifteen districts of Karnataka. Mean per cent grain discolouration of 12.87 during *kharif* 2017 and 13.24 during *Kharif* 2018 and per cent disease index of 12.04 during *Kharif*2017 and 12.27 during *Kharif* 2018 (Table 2, Fig.1, Fig.2).

These survey results are corroborate with previous reports from Saifulla (1997) who reported that grain discolouration of rice was maximum in hilly region varied from 5 to 50 per cent followed by costal region which varied from 0 to 50 per cent, whereas in plain region varied from 0 to 5 per cent during summer and 0 to 25 per cent in *Kharif.* During 1989 and1990, the incidence of rice grain discolouration was assessed in Bilaspur, Chamba, Hamirpur, Kangra, Kullu, Mandi, Sirmour, Solan and Una districts of Himachal Pradesh. Maximum grain discolouration was recorded at Rahlu in Kanga district (88.12%) and least was in Una district (7.60%) (Sharma and Vaid, 1990).

Rice grain discolouration was found to vary with variety and Negi and Das (2003) reported that 18 varieties, Narendra 80 and 97 experienced maximum grain discolouration (54.7%) and were followed by Narendra 359 (47.4%), Manhar (46.6%), Basmati 385 (45.4%), Saket 4 (45.3%), Phat Dhan 11 (41.2%), Phat Dhan 16 (40.3%), Phat Dhan 12 (39.4%), Improved Sarbati (39.3%), Improved Indrasan (36.8%), Pant Sugandha Dhan 15 (35.8%), Jaya (35.7%), Basmati 386 (33.9%), Phat Dhan 10 (31.2%), Taraori Basmati (30.7%) and Sarjoo 52 (29.2%), whereas minimum discolouration was observed in Pusa 44 (27.5%). Imran Arshad *et al.,* (2009) reported that the grain discolouration disease of rice is becoming a serious threat to rice cultivation during *Kharif* season as compared to summer season in hilly area of Pakistan.

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Table.1 Incidence of grain discolouration of rice in different ecosystems in Karnataka during *Kharif* 2017and *Kharif* 2018

						2017				2018			
Ecosystems	**Districts**	**Taluks**	**Villages**	**No of fields**	**Major varieties**	**Diseases Incidence (%)**	**Per cent disease index (PDI)**	**Mean Diseases Incidence (%) of ecosystem**	**Mean per cent disease index (PDI)**	**Diseases Incidence (%)**	**Per cent disease index (PDI)**	**Mean Diseases Incidence (%)**	**Mean per cent disease index (PDI)**
Irrigated Kabini and Kaveri	Chamaraj angar	Yalandur	Y.K.Mole	3	IR-64 MTU-1010 Gangavati sona Aman KRH-4	13.33	11.85	**12.16**	**11.59**	10.66	11.11	**12.22**	**11.27**
			Yariyuru	3		12.00	11.11			15.55	13.33		
			Maddur	3		09.33	10.37			08.88	08.15		
		Kollegal	Madhuvanahalli	3	IR-64 MTU-1001 Aman	16.00	12.59			13.33	12.59		
			Gowdalli	3		13.33	14.07			16.00	14.07		
			Uttamballi	3		10.66	11.11			11.10	08.89		
			District average			**12.44**	**11.85**			**12.58**	**11.35**		
	Mandya	Mandya	Mandya	3	Jaya IR-64 Thanu BR-2655 KRH-4	12.00	12.59			11.10	08.89		
			Holalu	3		10.66	9.63			13.33	12.59		
			Mallanayankanakatte	3		08.00	8.89			10.66	11.11		
		Maddur	Devarahalli	3	BR-2655 Jayakrishna	16.00	14.81			13.33	11.85		
			Doddaarasinakere	3		13.33	11.85			08.88	10.37		
			Alemanegate	3		12.66	12.59			10.66	08.89		
		Pandavapura	Pandavapur	3	MTU1010 BR-2655 Aman	10.66	11.11			15.55	13.33		
			Agatahalli	3		08.00	07.40			11.11	07.40		
			Alphahalli	3		09.33	08.89			08.88	11.11		
			District average			**11.18**	**10.86**			**11.50**	**10.61**		
	Mysore	Mysore	Suttur	3	Jyoti IR-64 Gangavati sona MTU-1010	14.66	13.33			16.00	14.07		
			Basavanapur	3		13.33	12.59			11.10	12.59		
			Horalawadi	3		10.66	10.37			10.66	08.89		
			District average			**12.88**	**12.07**			**12.58**	**11.85**		

Hilly upland	**Kodagu**	**Ponnampet**	**Hudikeri**	**3**	**Jaya Sona massuri Local**	**16.00**	**16.29**	**14.95**	**13.64**	**16.00**	**16.29**	**15.47**	**13.94**
			Srimangala	3		13.33	14.7			17.77	11.85		
			Balele	3		17.77	13.33			14.66	14.81		
	Uttara Kannada		**District average**			**15.70**	**14.56**			**16.14**	**14.31**		
		Sirsi	Yedurbail	3	Jaya KMP105 Abhilash Hemavati	10.66	08.89			10.66	13.33		
			Bashi	3		16.00	14.81			16.00	14.81		
			Gudnapur	3		13.33	12.59			17.77	12.59		
			District average			**13.33**	**12.09**			**14.81**	**13.57**		
Irrigated ecosystem of TBP and UKP	Raichur	Sindhanoor	Gorebal	3	BPT-5204 RNR-15048 Gangavati Sona Nellur Sona Kaveri Sona	13.33	14.81	**11.85**	**11.03**	11.10	11.85	**12.62**	**12.36**
			Sindhanoor	3		12.00	11.85			10.86	11.11		
			Javalagera	3		11.33	09.63			13.33	10.89		
			District average			**12.22**	**12.09**			**11.76**	**11.28**		
	Koppal	Gangavati	Basapattana	3	BPT-5204 Gangavati Sona Nellur Sona RNR-15048 Kaveri Sona	16.00	14.81			15.00	13.33		
			Heruru	3		14.66	13.33			11.11	10.89		
			Anegundi	3		12.59	11.85			13.33	12.59		
			District average			**14.41**	**13.33**			**13.14**	**12.27**		
	Bellari	Siruguppa	Siruguppa	3	BPT-5204 Gangavati Sona Nellur Sona Kaveri Sona	10.66	09.63			11.11	08.89		
			B.M.Sugur	3		12.00	12.59			12.00	12.59		
			Balakundi	3		13.33	14.81			13.33	11.11		
		Hospete	Kamalapur	3	BPT-5204 RNR-15048 Gangavati Sona Nellur Sona Kaveri Sona	9.33	08.89			09.33	08.89		
			Kampli	3		10.66	09.63			10.66	09.63		
			Ramasagara	3		13.33	12.59			11.10	08.89		
		Bellari	Emmignur	3	BPT-5204 Gangavati Sona Nellur Sona Kaveri Sona	12.00	11.85			12.00	11.85		
			Guttiganur	3		13.33	14.81			15.55	14.81		
			Kottal	3		12.66	12.59			08.88	07.40		
			District average			**11.88**	**11.93**			**11.55**	**10.45**		
	Yadgiri	Shahpur	Hothpete	3	RNR-15048	10.66	11.85			09.33	11.85		

			Shahapur	3	BPT-5204	12.00	12.59			12.00	08.89		
			Gogi	3	Gangavati Sona Nellur Sona Kaveri Sona	13.33	11.85			15.00	13.33		
			District average			**11.99**	**12.09**			**12.11**	**11.35**		
Irrigated Thunga and Bhadra	Shivamogga	Shivamogga	Gondhichatttanahalli	3	IR-64 BPT-5204 MTU-1000	09.33	08.89			11.10	08.89		
			Harakere	3		12.00	11.85			12.00	11.85		
			Holaluru	3		10.66	12.59			10.66	11.11		
			District average			**10.66**	**11.11**						
	Chikkamagaluru	Tarikere	H.Rangapur		RNR-15048 Jayashree BPT-5204 IR-64 MTU-1010	14.66	12.59			14.66	12.59	**11.85**	**11.03**
			Halasur	3		13.33	10.66			15.00	13.33		
			Hanne	3		12.00	09.33	**11.85**	**1.03**	12.00	11.11		
			District average			**13.33**	**10.86**						
	Davanagere	Channagiri	Kariganur		RNR-15048 Jayashree BPT-5204 IR-64 MTU-1010	09.33	10.66			11.10	10.66		
			Kasipur	3		11.33	09.33			12.00	12.59		
			Arehalli	3		10.66	08.89			10.66	08.89		
		Harihara	Nandigavi	3		12.66	11.85			12.66	11.85		
			Gondajji	3		08.00	08.89			08.00	08.89		
			Rajanahalli	3		09.33	09.63			13.33	11.11		
		Davanagere	Maragondanahlli	3		10.66	11.85			10.66	08.89		
			Kadlebalu	3		11.33	12.59			11.33	12.59		
			Avaragolla	3		09.33	08.89			08.88	07.40		
			District average			**10.29**	**10.28**						
	Bellari	Harapanahalli	Hiremegalegere		RNR-15048 Jayashre BPT-5204 IR-64	12.00	09.63			10.66	08.89		
			Nitur	3		10.66	08.89			12.00	11.11		
			Alavagulu	3		09.33	07.40			11.33	12.59		
			District average			**10.66**	**8.64**			**11.33**	**10.86**		
Coastal belts	Uttar Kannada	Uttar Kannada	Mundugodu	3	Jaya Rasi Intan	12.00	10.37			13.33	12.59	**15.00**	**13.67**
			Kumata	3		16.00	14.81			16.00	14.81		
			Honnavar	3		14.66	12.59			15.00	13.33		
			District average			**14.22**	**12.59**			**14.77**	**13.57**		
	Dakshina Kannada	Udupi	Barkur	3	Kajji Akki Intan Small Jaya	13.33	11.33			14.66	12.59		
			Kundapur	3		12.00	12.59			13.33	14.81		
			Udapi	3		14.66	13.33			16.00	15.55		
		Mangaluru	Mudbidari	3	Intan dwarf Small Jaya	16.00	14.81	**14.33**	**13.04**	15.00	13.33		
			Beltangdi	3		13.33	12.59			14.66	11.11		
			Kankanadi	3		17.33	16.29			17.77	14.66		
			District average			**14.44**	**13.49**			**15.23**	**14.56**		

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Table.2 Incidence of grain discolouration of rice in different ecosystems in Karnataka during *Kharif* 2 017 and *Kharif* 2018

						2017		2018	
Ecosystems	**No of districts covered**	**No of taluks covered**	**No of villages covered**	**No of fields covered**	**Major varieties**	**Diseases Incidence (%)**	**Per cent disease index (PDI)**	**Diseases Incidence (%)**	**Per cent disease index (PDI)**
Irrigated Kabini and Kaveri	3	6	18	54	IR-64,MTU-1010,Gangavati sona,Aman,KRH-4,Thanu BR-2655,KRH-4	**12.16**	**11.59**	**12.22**	**11.27**
Hilly upland	2	2	6	18	Jaya,Sona massuri,Local Jaya,KMP105,Abhilash Hemavati	**14.95**	**13.64**	**15.47**	**13.94**
Irrigated ecosystems of TBP and UKP command	4	6	18	54	BPT-5204,RNR-15048 Gangavati Sona,Nellur Sona Kaveri Sona	**12.62**	**12.36**	**12.22**	**11.35**
Irrigated Thunga and Bhadra	4	6	18	54	RNR-15048,Jayashree BPT-5204,IR-64,MTU-1010	**11.23**	**10.22**	**11.85**	**11.03**
Coastal belts	2	3	9	27	Jaya,KMP105,Abhilash Hemavati	**14.33**	**13.04**	**15.00**	**13.67**
	15	**23**	**69**	**207**	**Mean Average**	**12.87**	**12.04**	**13.24**	**12.27**

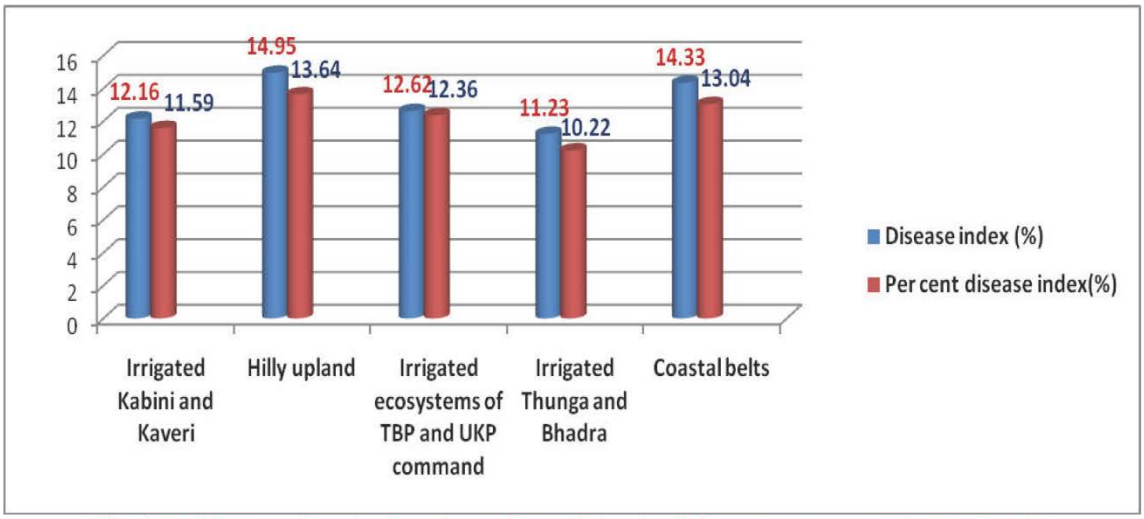

Fig.1 Incidence of grain discolouration of rice in different ecosystem in Karnataka during *Kharif* 2017

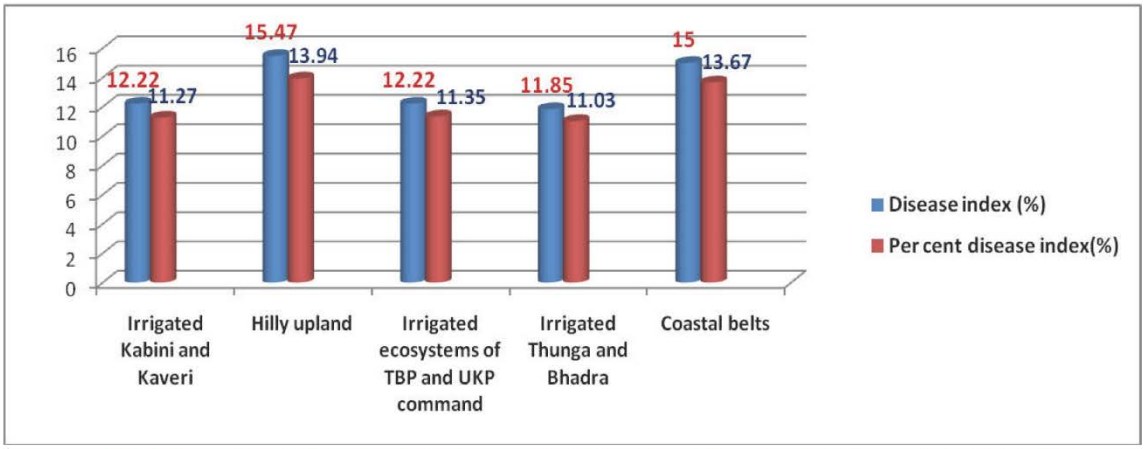

Fig.2 Incidence of grain discolouration of rice in different ecosystem in Karnataka during *Kharif* 2018

Total 287 seed samples consisting of 20 cultivars collected from major rice growing parts of Tamil Nadu and were used for analysis of health status. Among them, the per cent disease incidence ranged from 1.39 to 58.89 per cent. (Gopalakrishnan *et al.,* 2010) and Sumangala *et al.,* (2010) reported mean per cent incidence 10.34, 8.69 and 11.27 and mean per cent index 9.05, 8.39 and 10.70 in Raichur, Yadgir and Koppal, plain regions of North Eastern districts of Karnataka, respectively. The rice grain discolouration samples were collected from four districts of Andhra Pradesh. The percentage of discoloured grains from West Godavari district samples was ranged from 21.91 to 27.32 on weight basis and from 22.74 to 28.88 on grain number based analysis.

The corresponding percentages were; Krishna district - 23.02 to 28.62 and 24.34 to 30.35%, Guntur district - 22.58 to 28.76 and 24.57 to 30.46, and Nellore district - 22.88 to 28.74% and 25.05 to 30.81% (Divya, 2015).

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