"Influence of Silicon on leaf blast of rice (*Pyricularia grisea*) and their relationship on morphophysiological and yield attributing traits under drought stress"

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In partial fulfilment of the requirements for

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In

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(Plant Pathology)

By

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2020

CERTIFICATE- I

This is to certify that the thesis entitled, **"Influence of Silicon on leaf blast of rice (*Pyricularia grisea*) and their relationship on morphophysiological and yield attributing traits under drought stress"** submitted in partial fulfilment of the requirement for the degree of "**MASTER OF SCIENCE (Ag.)** In Plant Pathology" of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Miss Saloni Mandloi** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

All the assistance and help received during the course of the investigation has been duly acknowledged by him.

Signature

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This is to certify that the thesis entitled **"Influence of Silicon on leaf blast of rice (*Pyricularia grisea*) and their relationship on morphophysiological and yield attributing traits under drought stress"** submitted by **Miss Saloni Mandloi** to Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURE** in the Department of Plant Pathology, College of Agriculture, Rewa (M.P.) has been after evaluation approved by the by the External Examiner and Student's Advisory Committee after an oral examination of the same.

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Declaration and undertaking by the candidate

I, Miss **Saloni Mandloi** D/o **Shri Rupendra Mandloi** certify the work embodied in thesis **"Influence of Silicon on leaf blast of rice (*Pyricularia grisea*) and their relationship on morphophysiological and yield attributing traits under drought stress"** of rice and its management is my own first hand bonafide work carried out by me under the guidance of **Dr. S.K. Tripathi,** Principal Scientist & Head, Department of Plant Pathology, College of Agriculture, Rewa (M.P.) during 2019-20.

The matter embodied in the thesis has not been submitted for the award of any other degree / diploma. Due credit has been made to all the assistance and help.

I, undertake the complete responsibility that any acts of misinterpretation, mistakes, error of fact are entirely of my own.

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SALONI MANDLOI

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"Committed to the lord whatever do and your plan will succeed"

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Place: Rewa (M.P.)

Date :……/…../20….

SALONI MANDLOI

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LIST OF ABBREVIATION

CV	Cultivars
Cm	Centimetre
%	Percentage
@	At the rate of
d.f.	Degree of freedom
et al	And other
&	And
G	Gram
Kg	Kilogram
Ha	Hectare
i.e.	That is
JNKVV	Jawaharlal Nehru Krishi Vishwa Vidyalaya
Max.	Maximum
Min.	Minimum
No.	Number
mm.	Millimetre
Fig.	Figure
Viz.,	Which is/are
RH	Relative humidity
Hr.	Hour
SE(m)	Standard error of mean
C: B ratio	Cost: benefit ratio
q/ha	Quintal per hectare
Anova	Analysis of variance
S.V.	Source of variation
MSS	Mean sum of square
Ppm	Parts per million

Chapter – I

INTRODUCTION

INTRODUCTION

Rice (*Oryzae sativa* L.) is the staple food crop of over half of the world's population, and is also widely cultivated across the world, making it possibly the most valuable plant on earth. It provides 20 percent of the world's supply of dietary energy followed by maize and wheat. Rice grows in at least 114 countries and more than 50 have a capacity of 100,000 tons or more per year. The production of rice is estimated to be 128 Mt by 2025 to meet out the food requirement of growing population in India. Of the several factors known to destabilize rice yields, pests and diseases account for 30-40 percent crop losses. Most parts of the country regularly encounter complete crop failure due to epidemics of pests and diseases.

Rice(*Oryza sativa* L.) is one of the most important crop grown in India with world ranking first in area and second in total production next to China.It contributes 40% of total food grain production and cover 42% of the total cropped area. Productivity of the crop can be increased by adopting the hybrid rice and management of biotic stresses.The area of rice production in the world is 162.34mha with production 542.57million tons and productivity 4530kg/ha.(United States Department of Agriculture and Foreign Agricultural Service 2017-18).In India it has a largest area 43.19 million ha and second rank in production 110.15 million tons next to china with productivity of 2550kg/ha. In Madhya Pradesh, rice is being grown in area of 1.93 mha with production of 2.74 million tons and productivity 1768kg/ha (Ministry of Agriculture, Annual Report, 2017-18).The exploitation of local traditional varieties under upland ecosystem, improved susceptible varieties and poor agronomical practices are considered for the outbreak of leaf blast (*Pyricularia grisea*) causing 70-80% yield losses and becoming a major threat(Chuwa *et al.,*2014).

Rice crop growth and production adversely affected considerably due to attack of several fungal diseases and causing heavy economic losses to the crop. Among the major diseases, leaf blast caused by *Pyricularia grisea* is becoming serious menace to the crop for its cultivation in rainfed and

irrigated ecosystem and 75% grain yield was estimated (Padmanabhan 1965).

The disease may appear in seedlings, tillering, panicle stages and causing severe devastation to the crop under epidemic outbreak resulting considerable reduction in grain yield.Initial symptoms appear as white to gray-green lesions or spots, with dark green borders. Older lesions on the leaves are elliptical or spindle-shaped and whitish to gray centers with red to brownish or necrotic border. The spots are diamond shape, wide in the center and pointed toward either ends. Lesions can enlarge and coalesce, growing together, to kill the entire leaves.

The disease severity may be influenced by different factors like host resistance , soil types and weather conditions. Among the soil nutritional limiting factors Silicon (Si) is the second most abundant element available in soil and it is considered as an absolutely useful element for a large variety of plant (Nakata *et al.,2008*). It is concentrated in plant tissues in quantities similar to that of macronutrients. Considerable damages to plants caused by abiotic stresses such as drought stress, salinity stress, heavy metal stress and nutrient imbalance, as well as biotic stresses like insect pests and disease have been reported to be reduced significantly by Silicon application. Si is absorbed from soil in large amounts that are several fold higher than those of other essential macronutrients in certain plant species. Its beneficial effects have been reported in various situations, especially under biotic and abiotic stress conditions. The most significant effect of Si on plants, besides improving their fitness in nature and increasing agricultural productivity, is the restriction of parasitism. There has been a considerable amount of research showing the positive effect of Si in controlling leaf blast of rice. Silicon is distributed basipetally and accumulates greater amounts in the epidermal cells than in any other types of leaf cells (Elawad & Green, 1979). Once deposited, silica gel is immobile and is not redistributed to actively growing tissues (Elawad & Green, 1979; Ma *et al.*, 1989; Epstein, 1991).

Kawashima (1927) first demonstrated, under controlled conditions, that application of Si to rice plants increase desistance to blast (*Pyricularia grisea* Sacc. Cavara [teleomorph: *Magnaporthe grisea* (Hebert) Barr]. Silicon content in rice tissues also increased upon application of silica gel or solid silica to the soil. The results showed Si content in rice straw and husks were proportional to the amount of Si applied to the soil, and that the severity of blast on panicles was inversely proportional to the amount of the Si in rice tissues

Silicon fertilization has been reported to be efficacious in controlling and mitigating rice blast severity. Two different hypotheses are proposed for the ability of Silicon to lessen disease severity. The first hypothesis is a mechanical barrier against appressorial penetration, & second hypothesis is physiological roles in disease resistance (Farnaz Abed Ashtiani *et al.,*2012*)*. Keeping these facts in view, the study was under taken with the following objectives.

Objectives

1. Evaluation of rice genotypes against leaf blast of rice.
2. Bioassay of Silixol against *Pyricularia grisea* and their effect on sporulation.
3. Assessment of morpho-physiological parameters due to leaf blast under drought stress.
4. Influence of Silixol against leaf blast of rice and yield attributing traits of rice genotypes under drought stress.

Chapter – II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The available literature pertaining to the studies on "Influence of Silicon on leaf blast of rice (*Pyricularia grisea*) and their relationship on morphophysiological and yield attributing traits under drought stress" in the proposed objectives has been compiled and presented in this chapter under following subheads:

2.1 Survey, Surveillance and Collection of *Pyricularia grisea*.

2.2 Symptoms of leaf blast of rice.

2.3 Isolation of *Pyricularia grisea*.

2.4 Growth and development studies of *Pyricularia grisea*.

2.5 Effect of Silicon on leaf blast of rice (*Pyricularia grisea)*

2.6 Roll of Silicon application on the leaf blast suppression

2.1 Survey, Surveillance and Collection of the leaf blast (*Pyricularia grisea).*

Verma and Sengupta (1985) reported that, survey for diseases of rice, the principal cereal crop of Tripura, had led to the identification of as many as 17 diseases caused by fungi, bacteria, viruses and nematodes. The major diseases were blast, brown spot and bacterial leaf blight.

Reddy and Bonman (1987) stated that, severe epidemics of blast caused by *Pyricularia grisea* have occurred recently on rice in India and Egypt. During the wet and dry seasons of 1984 and 1985, Directorate of Rice Research survey teams recorded severe blast in the states of Andhra Pradesh, Karnataka and Tamilnadu. Cultivars affected were IR 50, In tan and improved locally developed NLR 9672, Tellahamsa and TKM 9. State Department of Agriculture production figures indicated a total loss from blast was of 140000 t.

Miah (2017) reported that Rice blast is the most destructive disease to rice production globally. The objective of this review is to know the fundamentals of rice blast disease and to know the different methods for controlling blast disease. Rice blast disease has been recognised in more than 85 rice-producing countries worldwide. Currently, more than 100 R genes for blast resistance have been identified in rice. These resistance genes can be introgressed into a susceptible variety through marker-assisted backcrossing. Infested residues and seeds are the primary inoculum sources to spread the disease. Considering the importance of this disease, various management approaches have been practiced to control blast disease. The use of resistant varieties is an important measure to manage the disease. This review will provide useful facts about the pathogen and its epidemiology, assessment of resistance genes and effective control measure of rice blast disease through breeding and management. This update information will be helpful and guide to the research students and rice breeders to develop durable blast resistant rice varieties.

2.2 Symptoms of leaf blast of rice

Padmanabhan (1974) and Manibhushan Rao, (1994) The lesions or spots first appear as minute brown specks, then grow to become spindle shaped pointed at both ends, several cm long and about 0.5 – 1.0 cm wide. The centre is greenish grey often showing a brownish margin. The size, colour and shape of the lesions, however, vary with different climatic conditions and also varietal response. Under favourable conditions on a susceptible cultivar several greyish spots may appear, become larger and broader and coalesce, leading to withering of the whole leaf.

2.3 Isolation of *Pyricularia grisea*

Padmanabhan *et al.* (1970) isolated *Pyricularia grisea* from samples of diseased leaves, necks, and nodes of the infected rice plant on Oat meal agar (OMA) with traces of biotin and thiamine (B and T). Cultures were purified by dilution method and single spore isolates were grown and multiplied on OMA + B & T at 25^0c.

Xia *et al.* (1993) collected the panicles with the symptoms of neck blast, washed once with sterile distilled water, and placed on moist filter paper in Petridishes at room temperature to induce sporulation. Conidia from the lesion surface were spread onto 3% water agar with a sterile loop and incubated overnight. Single germinating conidium was isolated and transferred to potato dextrose agar.

Vanaraj *et al.* (2013) studied and reported that isolates of *Pyricularia grisea* appeared as white on oat meal, rice polish and malt extract agar, grey on potato dextrose agar and whitish grey on rice agar. Spore induction was hastened on maize stem pieces than on rice and *Panicum repens* when spores of 11 isolates of *Pyricularia grisea* were compared, conidia of the isolate from *Pennisetum purpureum* were significantly bigger than the other isolates. The spores of rice isolates from Erode and Gopichettipalayam were significantly smaller in length and width.

Malviya (2014) used four culture media for the study of mycelial growth of *Pyricularia grisea* under *in vitro*. Among them, PDA supported maximum mycelial growth followed by Richard's Agar medium after 168 hrs of incubation. Then sporulation of *Pyricularia grisea* was observed in traces in Potato dextrose agar medium and Richard's Agar Medium after 168 hrs of incubation. However, Czapek-Dox Medium was not found effective for both vegetative growth and sporulation of the test pathogen.

2.4 Growth and development studies on *Pyricularia grisea*

2.4.1 Morphological Studies

Nishikado (1917) described morphology of *Pyricularia grisea* spores which measured 16 – 33 x 5 – 9µm. Usually 22 – 27 x 7 – 8 µm with a small basal appendage, other dimensions were, basal appendage 1.2 – 1.8 (1.6) µm in width, basal cell 4.8 – 11.5 (7.8µm), middle cell 1.8 – 11.5 (6.6 µm), apical cell 6 – 14 (7µm) in length.

Tochinai and Shimamura (1932) classified 39 isolates into nine forms on the basis of cultural characteristics. On steamed rice straw, the conidia of the isolates belonging to four forms were short, the mean value ranged from 19.3 to 22.8µm. The conidia of other five forms were long, the mean value ranged from 26.8 to 29.9µm. All isolates from the affected spikes or glumes of rice plants were of the long conidium type, while most isolates from the nodes were of the short conidium type. This suggests considerable difference in the length of conidia among the isolates of *Pyricularia* on rice.

Aoki (1955) measured 16 isolates in potato dextrose agar culture and showed that, the average length of the isolate ranged from 21.2 to 28.4µm, and the average width from 7.3 to 9.0µm.

Ono and Nakazato (1958) observed that, the size of conidia of *Pyricularia grisea* varied with the culture media also.

Sujuki (1974) observed the accuracy of disease forecasting by considering the number of spores with wind velocity and by forecasting the number of rainy days.

Rahnema (1979) showed that longer duration of conducive condition viz. Relative humidity and darkness before onset of the day period increased conidia germination and appressoria formation.

Mijan Hossain (2000) observed mycelium in cultures was first hyaline in colour, then changed to olivaceous, 1 – 5.2 µm in width, septate and branched. The spore measurements were 15 – 22 µm x 4 – 7 µm (Average, 17.4 µm x 5.2µm).

2.4.2 Cultural Studies

Nishikado (1927) obtained good growth of *Pyricularia grisea* isolated from Oryza sativa L. on decoction of their host material.

Ramakrishnan (1948) observed linear growth of the colonies of the *Pyricularia* isolated from rice. On standard medium agar, Oat meal agar,

French bean agar and decoction agar made out of the leaf material of rice. He also determined the weight of mycelial mat produced by the isolates in the standard medium, Richards's medium, Browns medium and decoctions of leaf material of rice. The isolates produce d good growth on the decoctions of their host material.

Sun *et al.* (1989) studied the effects of 17 media on 41 isolates of *Pyricularia grisea*. Theyfound that, corn meal and rice straw agar media were most conducive for sporulation.

Awoderu *et al.* (1991) observed that linear growth of *Pyricularia grisea* in potato dextrose agar medium, while conidial production was greatest on 1 per cent soluble starch yeast extract agar.

Arunkumar and Singh (1995) studied *Pyricularia grisea* (*M. grisea*) from rice on different solid culture media. They found that, maximum colony diameter of rice isolate occurred on malt extract agar and Leonin agar.

Du Xinfa *et al.* (1995) stated that, *Pyricularia* isolates from hosts including rice and common weeds in rice fields sporulated abundantly on sterilized barley or sorghum grains.

Mijan Hossain (2000) observed that among the non-synthetic media, potato dextrose agar supported maximum radial growth (85.00 mm), next was host extract + 2 per cent sucrose agar medium (80.33 mm) followed by oat meal agar (75.00mm).

Cruz *et al.* (2009) observed the higher sporulation on wheat meal culture medium in alternate light, dark regime.

Tripathi and Jain (2005) evaluated bio-pesticides and fungicides for the leaf blast and seed discolouration of rice and found optimum response of propiconazole against the disease.

Pal *et al.* (2014) found that Azoxystrobin and Tricyclazole were the most effective fungicide for reducing the mycelial growth of *Pyricularia grisea.*

2.4.3 Physiological studies

2.4.3.1 Effect of temperature

Nishikado (1927) reported the optimum temperature for the mycelial growth of *Pyricularia grisea* to be 25^0c to 30^0c while minimum temperature for the growth of the species is 8^0C – 9^0C and thermal death point is 51^0C – 52^0C.

Chakrabatri and Wilcoxson (1970) observed that light stimulates sporulation of *Pyricularia grisea* .They found that there was a distinct interaction between temperature and light. It was noticed that ultra-violate light is most favourable for conidia production *Pyricularia grisea*.

Chakrabatri (1971) suggested that foliage infection was characterized by a minimum temperature of 17.5 ^{0}C and R.H. of 95.5 % and further rise in temperature increase the infection considerable.

Yoshino (1979) proved that maximum penetration of appressorium take place under a wide range of temperatures i.e. 18-30^0C but the inoculums period under high humid condition is directly related with disease development.

Huang *et al.* (1980) concluded the blast varied from place to place in a favourable temperature of 22-26^0C.

Murlidharan and Venkatrao (1980) studied for forecasting epidemic outbreak in the plains with the help of trap method at Nellore. They noted that minimum temperature below 20^0C and R.H. 90% and above generally prevail for many days during the month of December., January. and February when the blast become severe. It was further noticed that the use

of high level of nitrogen and seed rate resulted in increasing the blast infection.

Awoderu *et al.* (1991) observed that the minimum, optimum and maximum temperature for growth and conidial production of *Pyricularia grisea* were 10^0C, 25^0C and 37^0C, respectively.

Okeke *et al.* (1992) noted that the growth of *Pyricularia grisea* was optimum at 28^0C, moderate at 23^0C and minimum at 15^0C and growth was inhibited at a temperature of 37^0C.

Arun Kumar and Singh (1995) studied the differential response of *Pyricularia grisea* isolates from rice, finger millet and pearl millet to temperature. They reported that all the isolates exhibited maximum growth at 30^0C.

Tripathi *et al.* (1997) reported maximum leaf blast severity in the second fort-night of October followed by first night of November when the maximum and minimum temperature varied between 31.5 to 18.1^0C- 16.6^0C and relative humidity 90-95%, respectively.

Kapoor *et al.* (2004) studied the disease severity of leaf blast during 1997, 1998 and 1999 in Kangra district, Himachal Pradesh and found that high humidity > 80%, prevalence of low temperature (16-19^0C) and maximum temperature (<28^0C) for 6-8 days or cloudy weather and 5-6 rainy days in a week were predisposing factor for disease development.

Behera *et al.* (2008) observed maximum and minimum temperature had a negative correlation to the aerospore count of *Pyricularia grisea. Maximum* temperature, minimum temperature, afternoon relative humidity and rainfall exhibited a negative correlation to the percentage of spores causing grain discolouration. Whereas, maximum temperature had significant impact on spore count for grain discolouration. The most favourable weather condition for was at maximum temperature (30-32^0C) and minimum temperature (16.8-21.9^0C).

Shafaullah *et al.* (2011) studied the effect of epidemiological factors (temperature, relative humidity and rain fall) on the incidence and severity of paddy blast (*Pyricularia grisea*) and found that humidity is positively correlated with rice blast i.e. 0.95, 0.90 0.99, 0.89, 0.93 respectively.

2.5 Effect of Silicon on leaf blast of rice (*Pyricularia grisea*)

Onodera (1917) A Japanese plant nutrient chemist, the first researcher who suggested that Silicon was involved in rice resistance to blast.

Takahashi and Okuda (1964) reported silicon generally decreased iron and manganese uptake by rice. This effect favourably influenced the growth and ripening of rice especially when the phosphorus supply was low. Thus, silicon increased the phosphorus/iron, phosphorus/manganese ratios and promoted the translocation of absorbed phosphorus to top of the panicle. Silicon did not show a substitution effect for phosphorus to rice when the phosphorus supply was high. Silicon also decreased an excessive phosphorus uptake and prevented poor fructification induced by an overdose of phosphorus.

Tanaka and Kawano (1965) showed that the leaf openness of the second leaf from top is conducive. The supply of silica resulting in physical environment leading to better aeration, root activity, nutrient absorption and the consequent complementary effect would have resulted in higher grain and straw yield of rice.

Yoshida *et al.* (1969) observed that leaf erectness decreases with increasing N application but Si application increases leaf erectness, decreasing mutual shading caused by dense planting and high N application.

Yoshida (1981) evaluated two sources of Silicon on the blast occurrence in rice seedlings; silica gel and potassium silicate. The silica gel application at 200 or 250 g per nursery bed (2.5 kg soil) limited the blast

occurrence to 10% of the control (without application). Potassium silicate application at 12 g per nursery bed was reported that Silicon addition to soils increased rice yields up to 10% and these increased yields could exceed 30% where leaf blast was severe.

Nayar *et al.* (1982) conducted a field experiment on an inceptisol in the dry season to study the changes in content and uptake of silica in relation to growth and yield of 12 rice varieties in the duration range of 90 to 140 days. The grain yield was in the range of 4.6 to 8.4 t ha-1 which resulted in total removal of 439 to 1308 silica kg ha-1 by crop.

Sawant *et al.* (1994) reported that in lateritic soil the RHA treatment improved the plant vigour and at times increased the number of tillers per hill and grain yield.

Korndorfer *et al.* (2001) studied the relationship between rice plant and yield and reported that lower silicon straw concentration was associated with lower relative yield.

Sudhakar *et al.* (2004) studied that the application of S through any of the sources as basic slag, rice straw compost and fly ash significantly increased dry matter, grain and straw yields relative to the control (no Si). Although Si sources were statistically on par among themselves, basic slag tended to be better than rice straw compost followed by fly ash.

Mukherjee and Sen (2005) showed application of rice husk at 9 t ha-1 significantly increased the plant height, number of tillers per hill, dry matter accumulation, chlorophyll content and leaf area index. Rice husk and fertility levels had a significant and positive effect on grain and straw yield.

Singh *et al.* (2005) they reported that different Silicon levels significantly increased plant height, dry matter production, panicles per m^2, filled grains per panicle, test weight and yield of rice. The maximum grain yield (6588 kg/ha) was recorded with the highest level of Silicon, i.e. 180 kg Si/ha.

Surapornpiboon *et al.* (2008) showed that under drought condition supplemental Si application in the rice culture solution would ameliorate the decrease of stomatal resistance and lead to the increase of dry weight, relative water content and Si concentration in leaf blade tissue

Nakata *et al.* (2008) Silicon is the second most abundant element in soil and it is considered as an absolutely useful element for a large variety of plant.

Shashidhar *et al.* (2008) reported that application of calcium silicate at 2 t/ha was found to be effective in increasing plant height, number of tillers per hill and panicle length over the control, and resulted in 25 - 30 % higher grain yield.

Kamenidou *et al.* (2009) Silicon ability to reduce transpiration and to increase photosynthesis rates in rice. These effects may be related to the distribution of silicon in the cell wall as a double Silicon-cuticle layer and also its role as a mechanical barrier against pathogens.

Jawahar and Vaiyapuri (2010) during 2008-2009 to study the effect of Sulphur and Silicon on growth and yield of rice indicated that Sulphur @ 45 kg/ha and Silicon 120 kg/ha recorded highest values for growth (plant height, number of tillers per plant and dry matter production), yield attributing characters (number of panicles per m^2 and number of grains per panicle) and grain yield of rice.

Muriithi *et al.* (2010) evaluating different rice blast management approaches using different sources of Silicon reported that chemical Silicon sources were significantly effective in increasing rice biomass. Calcium silicate greatly increase total number of productive tillers, thousand seeds weight, plant height and grain yield.

Ghanbari *et al.* (2011) reported that Silicon application increased number of filled spikelet's and decreased blank spikelet.

Nwite *et al.* (2011) evaluated the effects of the different ash materials and their mixtures as wood ash, leaf ash and rice husk ash @ 10 t ha-1 soil application to rice crop. The results showed improvements in soil pH, organic carbon and total N in the amended plots over the control. Rice grain yield increased due to the soil amendments from 1.8 to 6.5 t ha-1 in the first year and from 2.1 to 6.8 t ha-1 in the second year with leaf ash consistently giving the highest values.

Rambo *et al.* (2011) studied that chemical conversion of micronized RHA to produce xerogel silicas was shown to be possible way of making use of this inconvenient agricultural residue. The tests of xerogel silicas for the cultivation of rice indicated that these sources of silicon provided increments in the soil Si content and as a consequence, increasing the grain yield and dry matter production in the rice plant leaves.

Ahmed *et al.* (2011a, 2011b) reported that Si could decrease membrane permeability of sorghum under water deficit induced by polyethylene glycerol.

2.6 Role of Silicon application on the leaf blast suppression

Swain and Prasad (1991) quantified the Si concentration in roots of rice varieties and found that those genotypes with greatest concentration of Si had greater resistance to root knot nematodes (Meloidogyne spp) and that Si increased with plant age.

Yoshida *et al.,* (1959) Okuda and Takahashi, (1961), Ma *et al.,* (1989) and Lee *et al.,* (1990)There were many reports, found thatapplication of silicon during the reproductive growth stage is most important for plant growth and also increased thefinal yield of rice.

Ishiguro (2001) and Hayasaka *et al.* (2005) Silicon would increase resistance of rice to blast disease, subsequent studies have also confirmed that the application of Silicon is an effective method to reduce and control rice blast disease.

Maekawa *et al.* (2001) Resistance of rice blast was enhanced by silicon application, and that disease index for leaf and neck blast was reduced by 50.5 and 26.8% respectively.

Wang *et al.* (2001) Si fertilizers have been applied repeatedly to improve rice production by enhancing resistance to disease and increasing yield.

Chanchareonsook *et al.* (2002) reported that application of NPK fertilizer in combination with Si increased the total number of tillers in rice.

Fautex *et al.* (2005), Fautex *et al.* (2006) and Vivancos *et al.* (2015) Silicon is considered as non-essential for plant growth, but it helps in alleviation of biotic and abiotic stresses faced by the plants.

Hayasaka *et al.* (2005) Investigated the content of SiO_2 which was necessary for rice blast disease.

Singh *et al.*, (2005) Si improves high interception of light by keeping leaves erect there by stimulating canopy photosynthesis in rice.

Buck *et al.* (2008) studied the effect of silicon absorption through the leaves on rice blast (*Pyricularia oryzae*) control using potassium silicate (K_2Sio_3) in different doses (0,1,2,3,4,8 or 16 g Si L-1) and number of spraying at two solutions having different pH. Potassium silicate pulverization on the leaves did not increase Si absorption or accumulation by the plant; however, there was a reduction on blast incidence. The greatest reduction on blast incidence was observed at 4 g Si L-1, regardless of solution pH.

Yavarzadeh. *et al.* (2008) who reported that increase in plant height could be due to deposition of silica on the plant tissues causing erectness of leaves and stem.

Jawahar and Vaiyapuri (2010) Larger leaf area and high chlorophyll content might have accumulated more photosynthates and produce higher biological yield (DMP).

Kamenidou *et al.* (2009) These effects may be related to the distribution of silicon in the cell wall as a double silicon-cuticle layer and also its role as mechanical barrier against pathogens and pest.

Guntzer *et al.* (2012) Silicon provides strength and rigidity to the cell wall, improves growth, health and productivity develop potential to withstand drought, frost and salt stresses and decreases lodging, boosts the plant's resistance against insects, pests and disease-causing pathogens.

Jawahar *et al., (*2015) Rani *et al.,* (1997), Ahmad *et al.,* 2013; and Patil *et al.,* (2017) Silicon also has a major role in increasing yield attributing characters like number of spikelets, filled spikelet percentage, test weight and total grain yield in rice.

Chapter- III

MATERIAL AND METHODS

MATERIALS AND METHODS

The present study on "Influence of Silicon on leaf blast of rice (*Pyricularia grisea*) and their relationship on morphophysiological and yield attributing traits under drought stress." was carried out during 2019-20 at experimental field of All India Coordinated Rice Improvement Project, College of Agriculture, Rewa (M.P.). The materials used and methodologies adopted during the course of present study are described below.

3.1 Experimentation site

The experiment was conducted under All India Co-ordinated Rice Improvement Project JNKVV, College of Agriculture Farm, Rewa (M.P.) during *Kharif* season, 2019. The site was selected in such a way that it was representative of one of the major rice growing area of the region. The topography of the experimental site was fairly levelled. All the required facilities including irrigation, transportation etc. was available on the site.

The soils are normal with pH value 7.3 and electrical conductivity varied from 0.37-0.44 dSm^{-1}at 25^0C. The soils are low in available nitrogen, medium in available P_2O_5 and high in available potassium.

a) Texture : Silty clay loam
b) WP : 17.0 per cent (V/V)
c) FC : 31.0 per cent (V/V)
d) Soil depth : 3 m
e) Organic carbon : 0.56-0.60 per cent

3.2 Climate and weather conditions

Rewa is situated in North Eastern part of Madhya Pradesh at 24° 31' North latitude, 81°15' East longitude and 360 meters above mean sea level. It has sub tropical climate with hot and dry summer and cold winters which are the main features of the region. The average annual rainfall of the region is 1200 mm.

The total rainfall throughout the cropping season was 850.8 mm received in 41 rainy days in *Kharif* (Table 3.1). The maximum and

minimum temperature recorded during the crop season was 41.03ºC and 10.74ºC in the month of June and December respectively.

3.3 Meteorological data

The meteorological data (Maximum temperature, minimum temperature relative humidity and rainfall) for the *kharif* season, 2019 were obtained from the Department of Agricultural Meteorology, JNKVV, College of Agriculture, Rewa.

Table 3.1: Weekly meteorological data during *kharif* season 2019-2020

Standard Week	Period		Temperature (0^c)		Rainfall (mm)	Rainy	Relative humidity	
	From	To	Max.	Min.	(mm)	days	Min.(%)	Max.(%)
23	04-Jun	10-Jun	41.03	25.83	22.6	1	27.86	38.57
24	11-Jun	17-Jun	40.97	26.29	11.6	3	34.86	44.86
25	18-Jun	24-Jun	38.28	24.54	49.6	4	39.00	62.86
26	25-Jun	01-Jul	35.69	23.51	70.6	4	60.14	71.57
27	02-Jul	08-Jul	30.97	24.27	67.8	2	65.29	82.29
28	09-Jul	15-Jul	29.01	22.93	296.0	5	76.86	86.71
29	16-Jul	22-Jul	33.51	23.96	96.6	6	69.71	78.29
30	23-Jul	29-Jul	30.37	22.81	51.2	4	76.43	87.14
31	30-Jul	05-Aug	32.34	24.10	7.2	1	64.43	81.43
32	06-Aug	12-Aug	31.69	24.27	17.4	2	72.57	84.86
33	13-Aug	19-Aug	32.67	24.34	0	0	60.29	78.57
34	20-Aug	26-Aug	33.69	23.99	63.6	2	63.29	78.00
35	27-Aug	02-Sep	32.56	23.65	2.2	1	59.29	80.86
36	03-Sep	09-Sep	34.43	23.08	23.4	1	57.86	74.29
37	10-Sep	16-Sep	34.89	23.40	21.8	2	66.86	77.00
38	17-Sep	23-Sep	32.70	23.10	49.2	3	72.00	85.14
39	24-Sep	30-Sep	34.00	21.19	0	0	50.71	76.86
40	01-Oct	07-Oct	34.49	21.46	0	0	54.29	77.29
41	08-Oct	14-Oct	34.43	21.76	0	0	54.00	79.57
42	15-Oct	21-Oct	34.99	18.61	0	0	54.43	68.43
43	22-Oct	28-Oct	35.14	16.23	0	0	40.29	59.71
44	29-Oct	04-Nov	31.50	14.54	0	0	47.43	70.29
45	05-Nov	11-Nov	30.89	13.16	0	0	49.71	71.86
46	12-Nov	18-Nov	29.71	13.74	0	0	50.00	70.00
47	19-Nov	25-Nov	27.73	10.74	0	0	50.71	70.57
48	26-Nov	02-Dec	27.90	8.78	0	0	38.43	63.29
49	03-Dec	09-Dec	26.43	10.36	0	0	36.57	67.86
50	10-Dec	16-Dec	26.96	11.19	0	0	31.71	75.29
51	17-Dec	23-Dec	24.67	8.40	0	0	34.14	75.00
52	24-Dec	31-Dec	24.78	7.23	0	0	43.00	81.75
			32.3	**19.4**	**850.8**	**41**	**53.4**	**73.3**

Source: Meteorological Observatory, College Farm, Rewa (M.P.)

3.4 *In vitro* studies

3.4.1 Cleaning and sterilization of glassware

For all the laboratory studies, Borosil glassware was used. The glassware were washed with detergent powder and kept for one hour in cleaning solution containing 60g potassium dichromate, 60ml of concentrated sulphuric acid in one litre of water followed by washing under running tap water and rinsing twice in distilled water. Glassware was further air dried and sterilized in hot air oven at 160^0C for one hour.

3.4.2 Equipment's used

The following equipment's and materials were used in present investigation:

1. Autoclave
2. BOD incubator
3. Hot air oven
4. Forceps, needles, blades, inoculation needle
5. Laminar air flow
6. Spirit lamp
7. Electronic weighing balance
8. Refrigerator
9. Thermometer
10. EC meter
11. Leaf area meter

3.4.3 Isolation of pathogen (*Pyricularia grisea*)

The necrotic patches of diseased leaves were cut into small pieces. These pieces were surface sterilized by dipping in mercuric chloride solution (1:1000) for one minute and were washed by sterilized water for several times. The cut pieces were inoculated in sterilized Petri dish containing potato dextrose agar medium (Riker and Riker, 1936) amended with streptomycin sulphate under aseptic condition and kept in BOD incubator at 25 ± 1^0C for development of fungal growth. The fungus cultures were also maintained in culture tube to avoidcontamination.

3.4.4 Purification of pathogen (*Pyricularia grisea*)

Isolation techniques were used for getting pure culture in the media .The test fungus was transferred on sterilized potato dextrose agar medium(PDA) plates and kept in BOD for the development of mycelial growth at ± 20^0C.The marginal mycelial growth that developed subsequently was picked-up aseptically for sub-culturing. The sub culturing was done at an interval 15 days and preserved at temperature (20^0C) in refrigerator.

3.4.5 Identification & Pathogenicity of *Pyricularia grisea*

The identification of pathogenic fungi of rice blast were studied, which laid the foundation for further study as per objectives of the disease. The pathogenic fungi of rice blast was separated by using the conventional separation method of the fungi. The inoculation experiment was verified by Koch's postulates. The pathogen colonies of rice blast were identified by the morphological and cultural characteristics. The separation of the pathogenic fungi of rice blast was confirmed by inoculation experiment.

For sporulation of the fungus, rice grain media was used. First rice grain was sterilized in conical flask in an autoclave at 15lb psi (121.6^oC) for 20 minutes. Then the pathogen was inoculated in the sterilized rice grain and it was kept in a BOD at 25±1^oC.for sporulation. This spore suspension was again inoculated in fresh rice leaves following the procedure mentioned earlier. Leavesdeveloped similar type of blast lesion were kept in moist chamber in BOD at 25±1^oC for 3 days. The conidia both from leaf sample and from media were observed under microscope. Photograph of the spore (both in media and leaf sample) were taken with a binocular microscope fitted with Moticam 3.0 MP camera.

3.5 Experimental details *In vitro*

3.5.1 Studies on Cultural characteristics and mycelial growth of *Pyricularia grisea* in different culture media

Design : CRD

Replication : 04

Treatment : 05

Observation :Morphological characteristics of *Pyricularia grisea* radial growth of mycelium at different time in culture media.

Cultural characteristics of was studied in five culture media namely Potato Dextrose Agar (PDA), Oat Meal Agar (OMA), Czapek Dox Agar (CDA), Richards Agar medium and Corn Meal Agar (CMA). The composition of the used media was given as under:

Potato Dextrose Agar (PDA)

Composition	Quantities (g / litter)
Potato (peeled and sliced)	200
Dextrose	20
Agar-agar	20

Czapek-Dox Agar (CDA)

Composition	Quantities (g / litter)
Potassium nitrate (KNO_3)	10.00
Mono potassium di hydrogen phosphate (KH_2PO_4)	5.00
Magnesium sulphate (MgSO4.7H2O)	2.50
Ferric chloride (FeCl3)	0.02
Sucrose	50.00
Agar-agar	15.00

Richard Agar medium

Composition	Quantities (g / litter)
Potassium nitrate (KNO_3)	10.00
Mono potassium di hydrogen phosphate (KH_2PO_4)	5.00
Magnesium sulphate (MgSO4.7H2O)	2.50
Ferric chloride (FeCl3)	0.02
Sucrose	50.00
Agar-agar	15.00

Corn Meal Agar (CMA)

Composition	Quantities (g / litter)
Corn meal infusion from	50.00
Dextrose	2.00
Agar-agar	15.00

OAT Meal Agar (OMA)

Composition	Quantities (g / litter)
Oat meal infusion from	72.50
Oat meal	60.00
Agar-agar	12.50

For measuring the radial growth rate, 5 days old culture was inoculated in triplicate at the centre of 90 mm petri plate. Inoculum was in the form of 5 mm mycelial discs taken from margin of colonies grown on PDA plates. The plates were incubated at ambient temperature (25^0C) and the radial growth was measured (in mm) 48, 72, 96 and 120hrs after incubation. Colony characteristics (Growth type, growth pattern, colony colour etc.) were observed by visual observation of the growth pattern of test fungi after 120 hrs of inoculation. Pigmentation or production of any secondary metabolite was also inspected by colour production from the of culture plate.

3.6 Experimental detail *In vivo*

3.6.1 Symptoms produced by the disease

The characteristic symptoms produced by the disease in different varieties of rice were recorded by visual observations regularly in the experimental area as well as in College field. Rice blast symptoms produced by the disease on plant were recorded and infected samples were collected for further studies.

3.6.2 Evaluation of rice germplasm against leaf blast of rice under drought stress

Design : Split Plot Design

Fertilizer : 100:45:60, N: P: K (kg/ha)

Sub-plot treatment : 4 (Silixol)

Genotypes : 9

(V1. IIRRH122, V2. IIRRH131, V3. IIRRH132 V4. HRI174,

V5 KRH4, V6. JKRH3333, V7.US314, V8. 27P63

V9. Sahabhagidhan)

Date of transplanting: 06.08.2019

Silicon Treatment: 4

T1	Control
T2	Spray at 0.6% silicon at tillering, PI, 50% flowering and milky grain stage.
T3	Silicon + water stress water stress to be imposed by withholding irrigation
T4	Water stress only

Fig. 3.1: Layout plan of the field experiment

2

R1	R2	R3		R1	R2	R3
V_8	V_1	V_4		V_9	V_1	V_4
V_7	V_2	V_3		V_8	V_2	V_3
V_6	V_3	V_2		V_7	V_3	V_2
V_5	V_4	V_1		V_6	V_4	V_1
V_4	V_5	V_9		V_5	V_5	V_9
V_3	V_6	V_8		V_4	V_6	V_8
V_2	V_7	V_7		V_3	V_7	V_7
V_1	V_8	V_6		V_2	V_8	V_6
V_9	V_9	V_5		V_1	V_9	V_5
T_3				**T_2**		

2M

R1	R2	R3		R1	R2	R3
V_9	V_1	V_4		V_9	V_1	V_4
V_8	V_2	V_3		V_8	V_2	V_3
V_7	V_3	V_2		V_7	V_3	V_2
V_6	V_4	V_1		V_6	V_4	V_1
V_5	V_5	V_9		V_5	V_5	V_9
V_4	V_6	V_8		V_4	V_6	V_8
V_3	V_7	V_7		V_3	V_7	V_7
V_2	V_8	V_6		V_2	V_8	V_6
V_1	V_9	V_5		V_1	V_9	V_5
T_4				**T_1**		

Observations recorded

1. Weather parameters
2. Rainy days
3. Rainfall (mm)
4. Maximum and minimum temperature
5. Relative humidity (%)

Morphophysiological parameters

1. Germination %
2. Root and shoot length(cm)
3. Seedling vigour index
4. Plant height(cm)
5. Leaf area index (LAI)
6. No. of tiller/plant
7. Relative water content (RWC)
8. Membrane stability index (MSI)

Yield components

1. Total dry matter (TDM)g
2. No. of panicle/plant
3. No. of grain/panicle
4. 1000 grain weight(g)
5. Grain yield(q/ha)
6. HI (harvest index) %

3.7 Observations and their procedures

Observations of the characters under study were recorded for comparing the effect of varieties and effect of fungicides. For each observation, five randomly selected plants were tagged from each plot and used further for observations. The mean values of the recorded data were taken as the actual values of the respective characters.

(A) *In vitro* studies:

Seed germination study was carried out *In vitro* by using mannitol 1% solution along with Silicon different treatment combinations. Mannitol was used to induce drought stress and Silicon was used as Silixol formulation @0.6% and distilled water was used for untreated check for evaluation of seed germination, root /shoot length and seedling vigour index.

Twenty seeds of each tested genotypes (09) were placed in petridishes (90mm) and treated with different treatment combinations for the study. Germination was finally recorded in each genotypes after seven days of plating and root /shoot length was recorded after 21days after plating .

Seedling vigour index was calculated by using the formula:

Seedling vigour index = (Root length +Shoot length) X germination %

Vigour index value was computed using the formula suggested by (Abdul-Baki and Anderson, 1973)

(B) Field studies:

(I) Plant height (cm)

Height of the five tagged sample plants were measured in centimetre at 50% flowering stage with the help of wooden scale and their mean value were worked out. Height of the main shoot of the sample plant was measured from the base of the plant to tip of the longest leaf. After panicle emergence, it was measured from base of the plant to tip of the panicle.

(ii) Number of tillers/plants

Number of tillers per hill was recorded for the five tagged plants at and 90 DAT and average was worked out. Each shoot arising from the plant was counted as tillers including the main shoot. The tillers/m^2 was also counted in each treatment from three random spots and average was calculated.

(iii) No. of tillers/m^2

Tillers bearing panicles were counted as effective tillers from each sample/hill and averages were worked out. The tillers/m^2 was also counted in each treatment from three random spots and average was calculated.

(iv) Length of panicle (cm)

The length of panicle was measured in centimetre from the base of rachis to tip of the panicle. The length of five sample panicles was measured and average was worked out.

(v) Grain yield (q/ha)

The yield of grains obtained from each net plot was recorded in kilograms after sun drying of grains and the grain yield per plot was converted into quintal per hectare.

Field and Laboratory experimental data were statistically analysed by following the Complete Randomized Design and Split Plot Design (Panse and Sukhatme 1967).

3.8 Disease incidence

Disease incidence was recorded as per SES (IRRI Scale) 1996.

Leaf blast Scale (SES IRRI, 1996)

Score	Percent Leaf area covered
0	No lesions
1	small brown specks pinhead size without sporulating centre
2	Small, roundish to slightly necrotic grey spots, about 1 -2 mm in Diameter, with distinct brown margin, lesions are mostly foundon lower leaves.
3	Lesion type is same as in scale 2, but significant number lesions are onthe upper leaves.
4	Typical sporulating blast lesions, 3mm or longer, infecting <2% of the leaf area
5	Typical Blast lesions infecting 2-10% of leaf area.
6	Blast lesions infecting 11-25% of leaf area.
7	Blast lesions infecting 25-50% of leaf area.
8	Blast lesions infecting 51- 75% of leaf area.
9	More than 75% leaf area affected.

The percent disease index (PDI) was calculated by adopting the formula:

$$\text{PDI} = \frac{\text{Sum of numerical ratings}}{\text{Total numbers of plants observed X maximum disease rating}} \text{ X } 100$$

The disease index (%) value was transformed by adopting the angular transformation table (Snedecor and Cochran 1967).

Ten observations were maintained for each variety and averages were recorded for taking disease observations under study.

Apparent infection rate (r)

Apparent infection rate (r) per day was calculated by relative lesion height using the formula given by Van der Plank (1963).

$$r = \left(2.3 \frac{X_2}{(t_2 - t_1)} \text{Log}_e \frac{}{X_1} \right)$$

Where,

r is the apparent infection rate per day

t_1 and t_2 is the initial and final time for disease recorded

X_1 and X_2 are the proportions of lesion height at time t_1 and t_2, respectively.

Area under Disease Progress Curve (AUDPC) was calculated with the formula given by (Das *et al.*, 1992; Sharma *et al.*, 2004)

$$\text{AUDPC} = \sum_{i=1}^{n-1} [\{(X_i + X_{(i+1)}/2\} (t_{(i+1)} - t_i)]$$

Where,

X_i is the Rice blast severity on the date,

t_i is the day and the number of scoring days

3.9 Statistical analysis

Wherever, required the experimental data were analysed using Split Plot Design and Complete randomize designs.

The skeleton of ANOVA for CRD is given below:

Source of Variation	D. F.	Sum of square (S.S)	Mean sum of square (M.S.S.)	F ratio
Treatments	t – 1	SST	MST	MST/ MSE
Error	n – t	SSE	MSE	
Total	n – 1	SSTO		

The skeleton of ANOVA for Split Plot Design (SPD) is given below:

Source of variation	D.F.	Sum of source (S.S.)	Mean sum of square (M.S.S.)	F ratio
Replication	(r-1)	S^2R	MS^2R	
Main plot	(m-1)	S^2MP	MS^2MP	MS^2MP / MS^2E (I)
Error (I)	(r-1) (m-1)	S^2E (I)	MS^2E (I)	
Sub-plot	(s-1)	S^2SP	MS^2SP	MS^2SP / MS^2E (II)
Interaction	(m-1) (s-1)	$S^{2\ interaction}$	$MS^{2interaction}$	$MS^{2\ Interaction}$ / MS^2E (II)
Error (II)	m(r-1) (s-1)	S^2E(II)	MS^2E (II)	
Total	(rms-1)	TSS		

Estimation of Membrane Stability Index

Membrane stability index (MSI) of the excised leaves was measured at different growth stages. Fresh leaf material was weighed into a glass beaker containing reverse osmosis water. The beakers were immersed at 30°C for 3 h, and then the conductivity of the solution was measured (*C*1) with a conductivity meter. After boiling the samples for 2 min, their conductivity was measured (*C*2) again when the solution was cooled to room temperature. The percentage of electrolyte leakage was calculated (Cekic *et al.*, 2001).

Relative water content (RWC)

Rice leaf tissues were collected and weighed immediately to get the fresh weight (FW). The leaf tissues were rehydrated in water for 24 h until they attained full turgidity, surface-dried and reweighed to get the turgid weight (TW). Finally, the tissues were oven dried at 80°C for48 hrs. (until constant weight), and were reweighed to obtain the dry weight (DW). The RWC was calculated using the Equation 1 (Bhushan *et al.*, 2007)

$$\mathbf{RWC\ (\%) = (FW- DW/TW- DW) * 100}$$

where,

RWC = relative water content,

FW=fresh weight,

DW = dry weight,

TW = turgid weight.

Membrane stability index and electrolyte leakage

The method of Sullivan and Ross (1979) was used to measure electrolyte leakage (EL). To remove solutes from leaf surface and damaged areas in leaf samples (0.2 g), they were washed for three times with distilled water. The samples were placed in Pyrex test tubes (15 £ 25 mm), and incubated with 15 ml distilled water at 23°C for 24hin the dark. The test tubes

were kept at 25^0C. After a strong hand shaking of the test tubes, the electrical conductivity (EC) of the electrolytes was measured by a conductivity meter. Following the EC measurements, all samples were autoclaved for 15 min at 60C. The samples were then returned to 25C and EC was measured again. Membrane stability index (MSI) and EL were calculated by using the following equations:

$$MSI = \left(1 - \frac{c_1}{c_2}\right) X\ 100 \qquad EL = \frac{C_1}{C_2}$$

Where, C1 and C2 refer to the initial and final EC, respectively.

Chapter – IV

RESULTS

RESULTS

This chapter deals with the experimental results and findings of the study under taken on "Influence of Silicon on leaf blast of rice (*Pyricularia grisea* L) and their relationship on morphophysiological yield attributing traits under drought stress" during the course of investigation. The data obtained i*n vitro* and i*n vivo* studies were statistically analyzed by using the appropriate design and interpreted in the chapter given below:

(A) *In vitro* studies:

4.1 Isolation of pathogen

4.2 Identification and purification of *Pyricularia grisea*

4.3 Effect of different media on mycelial growth of *Pyricularia grisea*

4.4 Effect of temperature on mycelial growth of *Pyricularia grisea*

4.5 Effect of pH on mycelial growth of *Pyricularia grisea*

4.6 Influence of Silixol on mycelial growth of *Pyricularia grisea*

4.7 Influence of Silicon on Seed Germination, Root length, Shoot length and Seedling Vigour of rice genotypes

4.1 Isolation of pathogen

The necrotic patches of leaf blast infected leaves were cut into small pieces. These pieces were surface sterilized by dipping in mercuric chloride solution (1:1000) for one minute and were washed by sterilized water for several times. The cut pieces were inoculated in sterilized Petri dish containing potato dextrose agar medium (Riker and Riker, 1936) amended with streptomycin sulphate under aseptic condition and kept in BOD incubator at 25±1^{0}C for development of fungal growth. The fungus cultures were also maintained in culture tube to avoidcontamination.

4.2 Identification and purification of *Pyricularia grisea*

4.2.1 Identification of *Pyricularia grisea*

The identification of pathogenic fungi of rice blast were studied, which laid the foundation for further study of the pathogenesis of the disease and effective prevention and control. The pathogenic fungus of rice blast was separated by using the conventional separation method of the fungi. The pathogenecity test was carried out in pots using susceptible genotypes and confirmed the Koch's postulates. The pathogen colonies of rice blast were identified by the morphological and cultural characteristics. The separation of the pathogenic fungi of rice blast was confirmed by inoculation experiment and morphological parameters of *Pyricularia grisea* were studied after staining of the spores and mycelia using binocular microscope. For sporulation of the fungus, rice grain media was used. First rice grain was sterilized in conical flask in the autoclave at 15lb psi (121.6^{o}C) for 20 minutes. Then the pathogen was inoculated in the sterilized rice grain and it was kept in a BOD at 25±1^{o}C. for sporulation This spore suspension was again inoculated in fresh rice leaves following the procedure mentioned earlier. Leaves developed similar type of blast lesion were kept in moist chamber in BOD at 25±1^{o}C for 3 days. The conidia both from leaf sample and from media were observed under microscope. Photograph of the spore (both in media and leaf sample) were taken with a binocular microscope fitted with Moticam 3.0 MP camera.

4.2.2 Purification of *Pyricularia grisea*

Fungus isolation techniques were used for getting pure culture of the fungus was transferred on sterilized PDA plates. The marginal mycelial growth that developed subsequently was picked-up aseptically for sub-culturing. The sub culturing was done at an interval of 15 days and preserved at temperature (20±1^{0}C) in refrigerator.

4.3 Effect of different cultutre media on mycelial growth of *Pyricularia grisea*

Five culture media were evaluated for the study of mycelial growth of the tested fungus *Pyricularia grisea* under *in vitro*. The data presented the Table 4.3.1 and represented in graph 4.3.1 reveal that Oat meal agar media supported maximum mycelial growth (75.3mm) followed by PDA medium (58.2mm) after 144 hrs of incubation. The sporulation of *Pyricularia grisea* was observed in traces in Oat meal agar and Potato dextrose agar medium after 144 hrs of incubation. However, Corn meal agar, Czapek-Dox agar medium and Richard's medium were not found effective in inducing the sporulation and mycelial growth of test fungus (Fig. 4.3.1).

Table 4.3.1 Effect of culture media on mycelial growth of *Pyricularia grisea* in different period of incubation

S. No	Treatment	Mycelial growth diameter (mm) Period of incubation				
		72 Hrs	96 Hrs	120 Hrs	144 Hrs	Sporulation
1	Potato dextrose agar	17.2 (18.43)	28.1 (23.11)	49.3 (25.84)	58.2 (28.39)	Traces
2	Oat meal agar	39.1 (38.70)	60.2 (50.89)	61.7 (51.77)	75.3 (60.20)	Traces
3	Corn meal agar	10.2 (27.56)	17.2 (31.31)	22.8 (33.02)	34.4 (39.08)	None
4	Czapek's dox agar	11.4 (27.56)	23.0 (31.31)	29.7 (33.02)	31.3 (34.02)	None
5	Richard's Medium	13.3 (35.24)	24.7 (40.80)	36.7 (41.96)	41.7 (48.85)	None
Mean		15.66	25.14	37.68	47.02	
CD at 5%		1.06				
CV %		2.77				

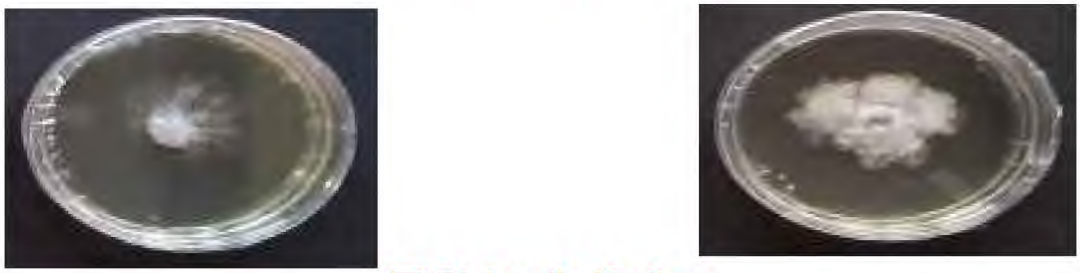
(Incubation period of 72 Hours) (Incubation period of 144 Hours)

(A) Potato Dextrose Agar

(A) Oat Meal Agar

(B) Corn Meal Agar

(C) Czapek's dox Agar



(E) Richard's Medium

Plate 1. Influence of Culture media on mycelial growth of *Pyricularia grisea* in different period of incubation

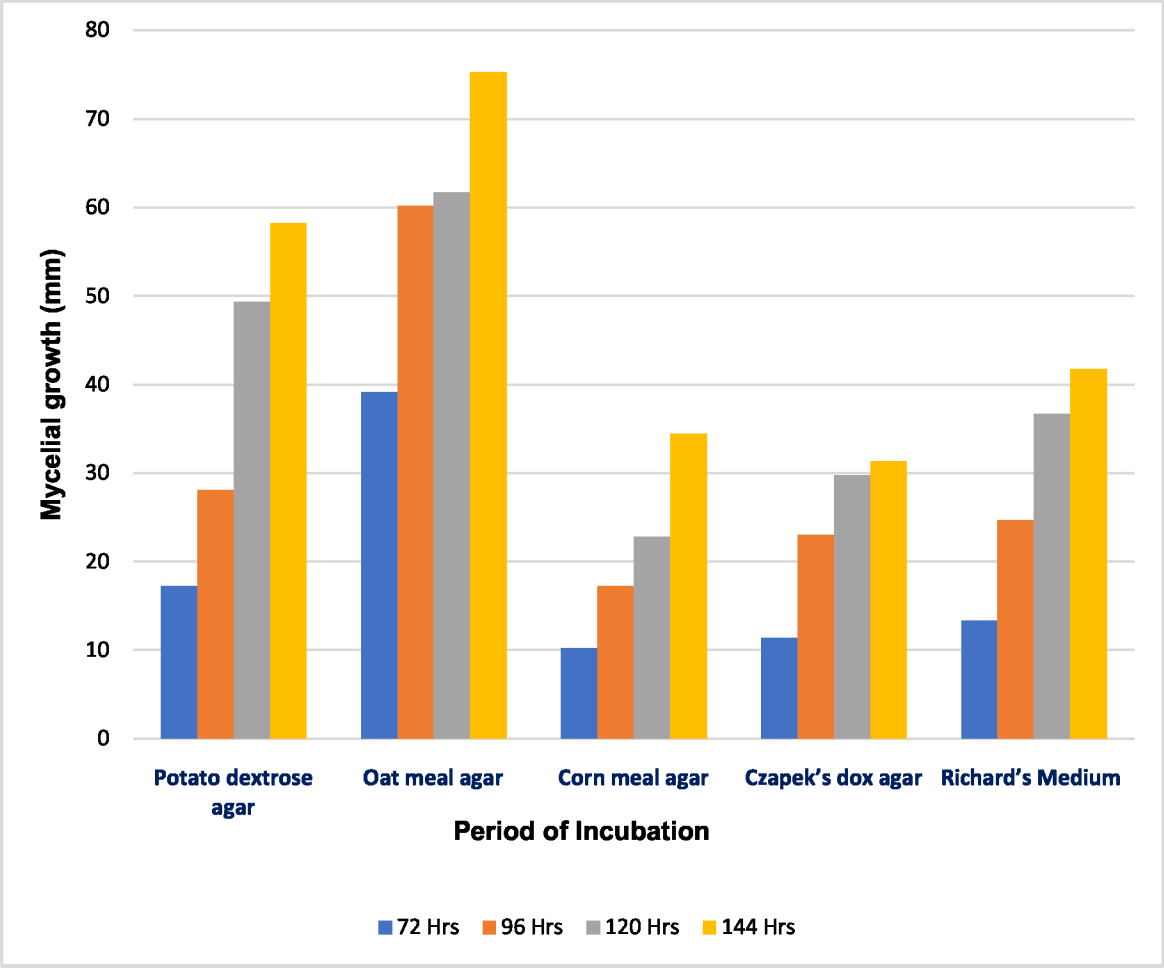


Fig 4.3.1 Influence of culture media on mycelial growth of *Pyricularia grisea* in different period of incubation

4.4 Effect of Temperature on mycelial growth of *Pyricularia grisea*

The experiment was carried out to study the effect of temperature on mycelia growth of *Pyricularia grisea* (Table 4.4.1). The variation in growth of fungus at different temperatures was recorded. It was observed that Maximum mycelial growth (72.1mm) occurred at 25°C followed by 20°C (70.5mm) after 144 hrs of incubation. It was recorded that higher temperature 35°C may suppressed the growth of fungus (21.8mm) and not found suitable for inducing the sporulation. (Fig.4.4.1).

Table 4.4.1 Effect of Temperature on mycelial growth and sporulation of *Pyricularia grisea*

S. No	Treatment ^{0}C	Mycelial growth Diameter (mm) Period of incubation				
		72 Hrs	96 Hrs	120 Hrs	144 Hrs	Sporulation
1	20	22.0 (21.06)	39.4 (31.08)	45.1 (38.21)	70.5 (45.09)	None
2	25	25.3 (26.33)	43.5 (38.13)	57.2 (45.71)	72.1 (57.12)	Traces
3	30	27.0 (17.02)	42.1 (23.04)	45.4 (34.12)	55.3 (40.17)	None
4	35	9.3 (14.22)	15.6 (22.16)	19.5 (24.52)	21.8 (31.87)	None
SEM ±		0.29	0.19	0.23	0.29	
CD at (5%)		0.66	0.42	0.53	0.66	

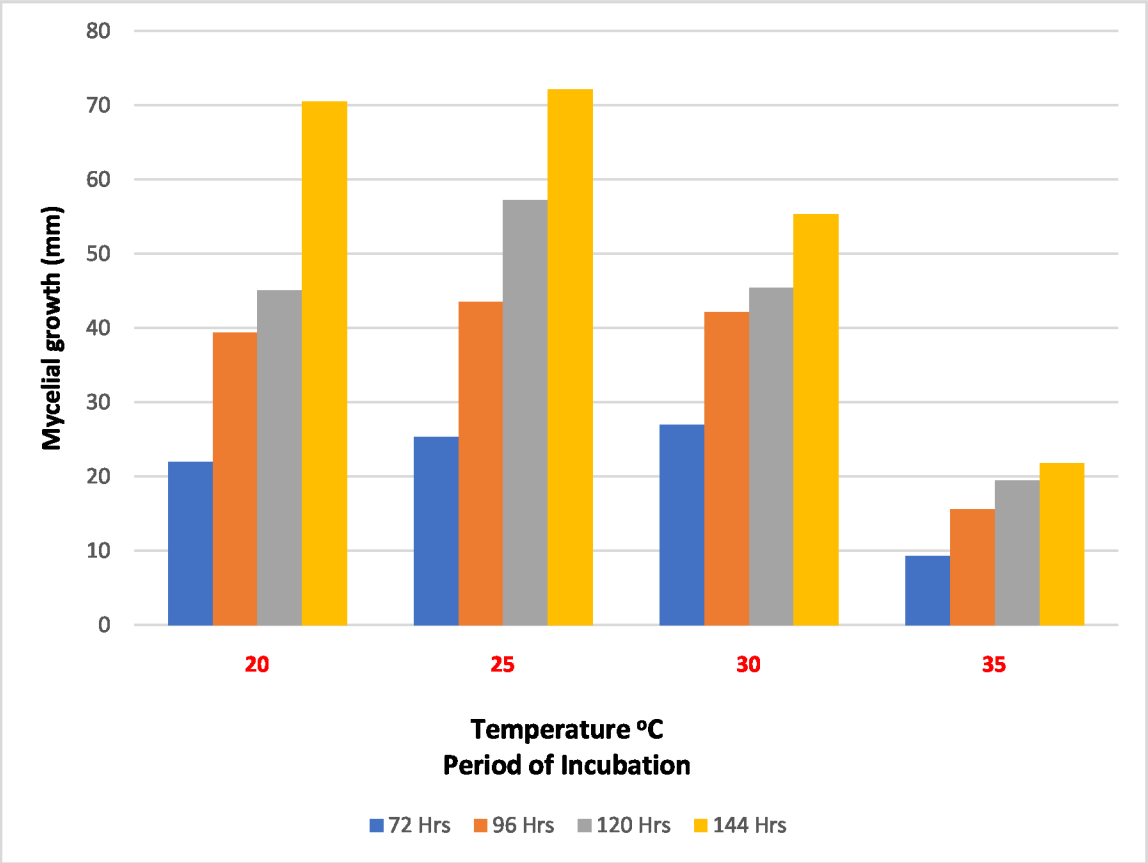
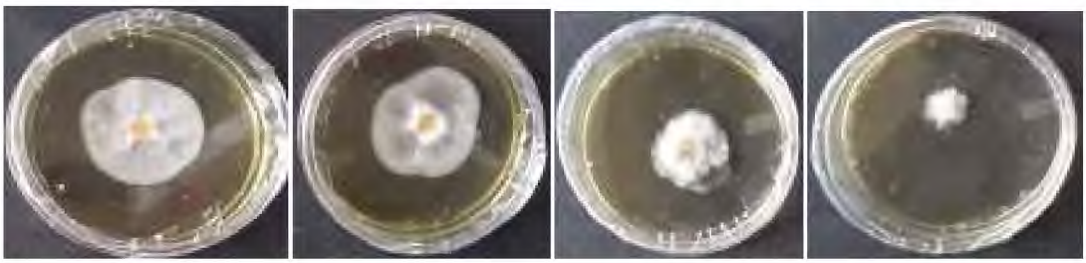


Fig. 4.4.1 Influence of temperature on mycelial growth and sporulation of *Pyricularia grisea*

Incubation period (72 Hrs.)



20^0C 25^0C 30^0C 35^0C

Incubation period (144 Hrs.)

Plate 2. Influence of Temperature on mycelial growth of *Pyricularia grisea*

Plate 3. A view of Pure culture and conidia of *Pyriculariagrisea*

4.5 Effect of pH on mycelial growth of *Pyricularia grisea*

The data on influence of pH on mycelial growth of *P. grisea* (Table 4.5.1) reveals that pH6 favoured the optimum growth (62.1mm) followed by pH5 (36.8mm) However, low pH4 had totally inhibited the growth of fungus. This clearly indicates that pH has a major role for the mycelial growth of *Pyricularia grisea in different tested medium.* It is obvious from the data that highly acidic and alkaline medium were found to be adversely affect on mycelia growth of test fungus however, pH6 and pH7 was found suitable for growth and sporulation of test fungus (Fig. 4.5.1).

Table 4.5.1 Influence of pH on mycelial growth and sporulation of *P. grisea*

S. No.	Treatment	Mycelial growth diameter (mm) Period of incubation				
		72hrs	96Hrs	120 hrs	144 hrs	Sporulation
1.	pH4	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	None
2	pH5	9.1 (17.56)	16.4 (23.89)	30.4 (33.46)	36.8 (37.35)	Traces
3	pH6	28.3 (23.04)	33.0 (29.23)	34.8 (31.72)	62.1 (52.01)	Traces
4	pH7	23.8 (21.08)	24.8 (22.61)	26.8 (24.32)	32.2 (29.01)	Traces
SEM ±		0.24	0.17	0.24	0.17	
CD at (5%)		0.54	0.39	0.54	0.39	

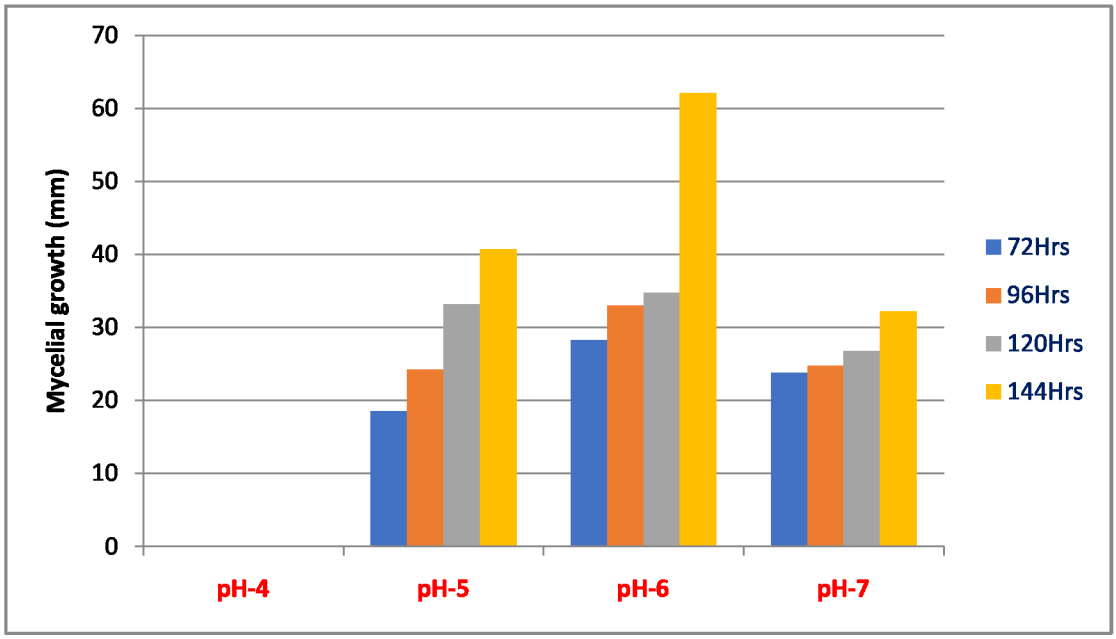


Fig. 4.5.1 Influence of pH on Mycelial growth and sporulation of *Pyricularia grisea*

4.6 Influence of Silixol on mycelial growth of *Pyricularia grisea*

Four different concentrations of Silixol @0.3%, 0.6%, 0.9% and 1.2% were evaluated against *Pyricularia grisea* in different period of incubation for the assessment of mycelial growth and Sporulation in Potato Dextrose agar medium (Table 4.6.1) and compared with standard fungicide Carbendazim 50WP@0.1% over untreated check. Among the treatment, Silixol@0.9% gave optimum mycelia growth (59.3mm) followed by Carbendazim (56.6mm) over Control (67.9mm). It was noted that minimum mycelial growth was observed in Silixol@0.6% (32.4 mm) at 144 hrs of incubation over standard fungicide check Carbendazim (36.6mm) and untreated check (77.9mm) .None of the Silixol sources induced the sporulation of *Pyricularia grisea*. except Silixol@0.6% where sporulation was observed in traces (Fig 4.6.1).

Table 4.6.1 Effect of Silixol at various concentrations on mycelial growth of *Pyricularia grisea* in different period of incubation

S. No	Treatment	Mycelial growth diameter (mm) Period of incubation				
		72 Hrs	96Hrs	120 Hrs	144 Hrs	Sporulation
1	Silixol@0.3%	50.4 (45.01)	51.2 (47.03)	52.8 (48.18)	53.2 (48.34)	None
2	Silixol@0.6%	29.4 (23.12)	30.1 (26.56)	30.2 (27.01)	32.4 (28.08)	Traces
3	Silixol@0.9%	57.2 (51.03)	58.1 (54.12)	58.2 (54.17)	59.3 (54.28)	None
4	Silixol@1.2%	52.8 (47.17)	53.1 (48.12)	55.2 (51.87)	57.5 (52.4)	None
5	Carbendazim50 WP @0.1%	35.2 (28.12)	35.7 (30.78)	36.1 (32.04)	36.6 (32.12)	None
6	Control	73.4 (58.19)	75.2 (59.12)	76.3 (59.17)	77.9 (59.28)	None
Mean		51.4	52.2	53.13	54.4	
CD at 5%		1.10				
CV %		2.77				

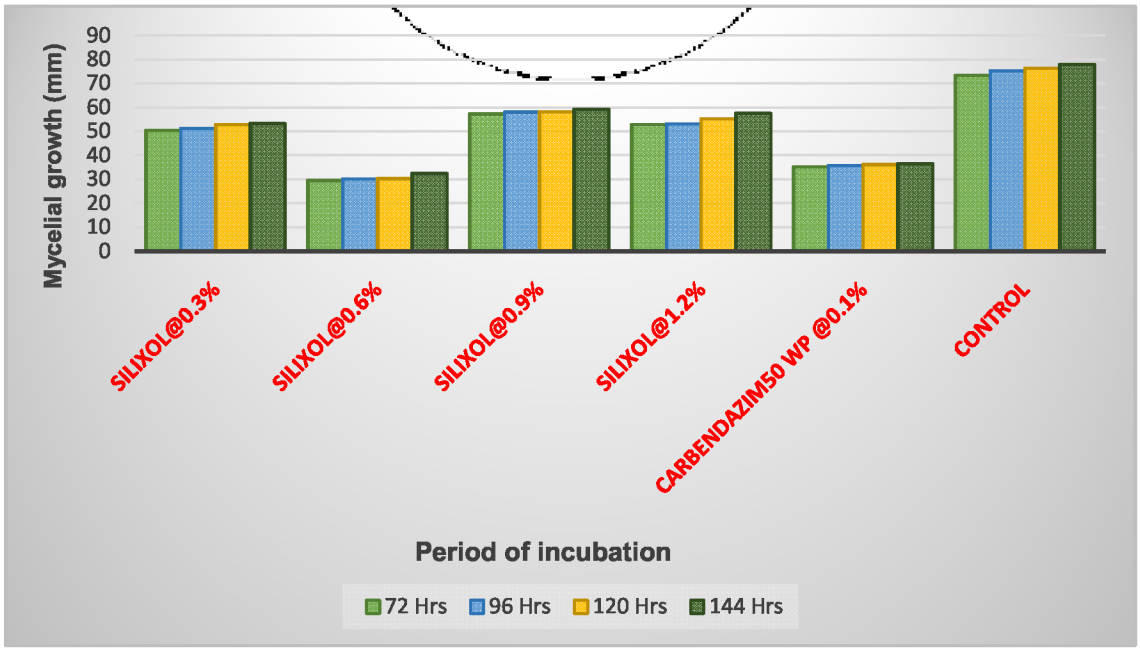


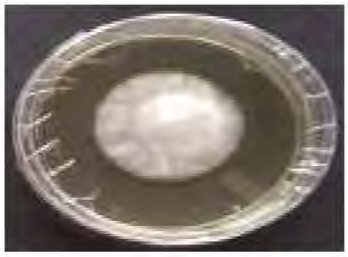
Fig.4.6.1 Influence of Silixol at various concentrations on mycelial growth of *Pyricularia grisea* in different period of incubation

(Incubation period of 72 Hours) (Incubation period of 144 Hours)

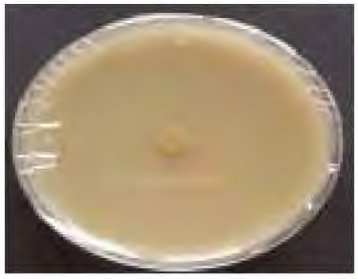

(A) Slixol@0.3%


(B) Silixol@0.6%


(C) Silixol@0.9%




(D) Silixol@1.2%




(E) Carbendazim 50WP@0.1%


(F) Control

Plate 4. Influence of Silixol at different concentration on mycelial growth of *Pyricularia grisea*

4.7 Influence of Silicon on Seed Germination, Root length, Shoot length and Seedling Vigour of rice genotypes

4.7.1Germination (%)

The effect of Silixol (@0.6%) on germination percentage was compared with two different conditions ie., irrigated and drought and it was found that germination percentage is higher in all the nine genotypes of rice under irrigated condition as compared to drought condition. Genotypes and treatments differences were significant, but their interactions were non-significant (Table 4.7.1).Under irrigated condition maximum germination percentage were recorded in US-314 (89%), Sahabhagidhan (89%), JKRH3333 (88%) and KRH-4 (88%), whereas, under drought condition these genotypes showed 68%, 71%, 72% and 79% respectively. It was observed that 0.6% Silixol increases the germination percentage under drought condition. It was also observed that Silixol application decrease the germination percentage due to excess moisture under irrigated condition.

Among the tested genotypes, the maximum increased germination percentage were recorded in US-314(19.1%), 27P63 (19.1%), JKRH3333 (15.1%), SAHABHAGIDHAN (14.1%) and HRI-174(11.0%) under drought + 0.6% Silixol (T3) over drought treatment (T4).

4.7.2 Root length and Shoot length (cm)

In regard to root and shoot length (Table 4.7.1) it is obvious from the data that genotypes varied significantly in the irrigated and drought condition. Root & shoot length was reduced in all nine genotypes under drought condition (T4). It was noted that 0.6% Silixol application increased root and shoot length in almost all genotypes under drought condition. Among the tested genotypes, 27P63 (15.0 cm), KRH-4(14 cm) US-314 (14.0 cm) and IRRH-132 (13.0 cm) showed maximum root length, whereas maximum shoot length was recorded in genotypes, IRRH-132 (18.0 cm), 27P63 (18.0 cm) and US-314(16.0 cm) under drought condition with the application of 0.6% Silixol over drought only.

4.7.3 Seedling Vigour Index

In regard to seedling vigour index (SVI), the data (Table4.7.1) indicate that application of Silixol application @ 0.6% did not influenced the seedling vigour under irrigated condition whereas, it was significantly increased in drought condition over untreated check .it was increased seedling vigour index in all tested rice genotypes under drought condition. Among the tested genotypes maximum percent increase seedling vigour index was recorded in27P63 (27.9%), US-314 (27.0%),JKRH-3333 (18.3%) and Sahabhagidhan (17.1%), however minimum percent increase seedling vigour index was recorded inIIRRH-131(9.8%), HRI-174 (11.7%), KRH-4 (12.9%) under drought condition with the application of 0.6% Silixol.

Table 4.7.1: Influence of Silicon on Seed Germination, Root length, Shoot length and Seedling Vigour Index of rice genotypes.

Treatment	Entries	Germination (%)	Root length (cm)	Shoot length (cm)	Seedling Vigour Index
T1(Control)	IIRRH-122	87	18.8	22.6	3615
	IIRRH-131	85	18.3	21.5	3390
	IRRH-132	87	18.4	21.9	3517
	HRI-174	84	18.3	22.0	3401
	KRH-4	88	18.4	21.6	3527
	JKRH-3333	88	18.1	20.6	3422
	US-314	89	17.9	20.9	3462
	27P63	87	18.7	22.6	3610
	SAHABHAGIDHAN	89	18.9	23.8	3818
Mean		**87**	**18.4**	**21.9**	**3529**
T2 (Irrigated + 0.6% Silixol)	IIRRH-122	86	17.4	18.8	3105
	IIRRH-131	84	16.4	19.3	2990
	IRRH-132	85	16.5	19.5	3064
	HRI-174	82	17.0	19.0	2967
	KRH-4	87	17.3	17.5	3019
	JKRH-3333	85	16.3	17.8	2891
	US-314	88	16.3	20.1	3195
	27P63	86	18.0	21.4	3379
	SAHABHAGIDHAN	87	17.8	20.4	3340
Mean		**85**	**17.0**	**19.3**	**3105**

T3 (Drought + 0.6% Silixol)	IIRRH-122	81	14.2	17.8	2603
	IIRRH-131	78	12.1	16.9	2258
	IRRH-132	83	13.4	17.5	2569
	HRI-174	81	13.6	17.6	2539
	KRH-4	84	14.0	17.2	2633
	JKRH-3333	83	12.8	15.7	2374
	US-314	81	13.5	16.0	2385
	27P63	81	15.1	18.2	2683
	SAHABHAGIDHAN	81	14.6	19.3	2741
Mean		**81**	**13.7**	**17.3**	**2531**
T4 (Drought)	IIRRH-122	73	13.5	17.8	2274
	IIRRH-131	71	12.3	16.8	2056
	IRRH-132	77	12.4	16.2	2193
	HRI-174	73	12.9	18.1	2273
	KRH-4	79	12.7	17.0	2331
	JKRH-3333	72	12.5	15.3	2006
	US-314	68	12.6	15.0	1878
	27P63	68	13.5	17.5	2098
	SAHABHAGIDHAN	71	13.9	19.1	2340
Mean		**77**	**12.9**	**16.9**	**2161**
CD (0.05%)	T	1.56	0.274	0.389	76.697
	G	2.34	0.410	0.583	115.045
	TXG	NA	NA	1.166	NA

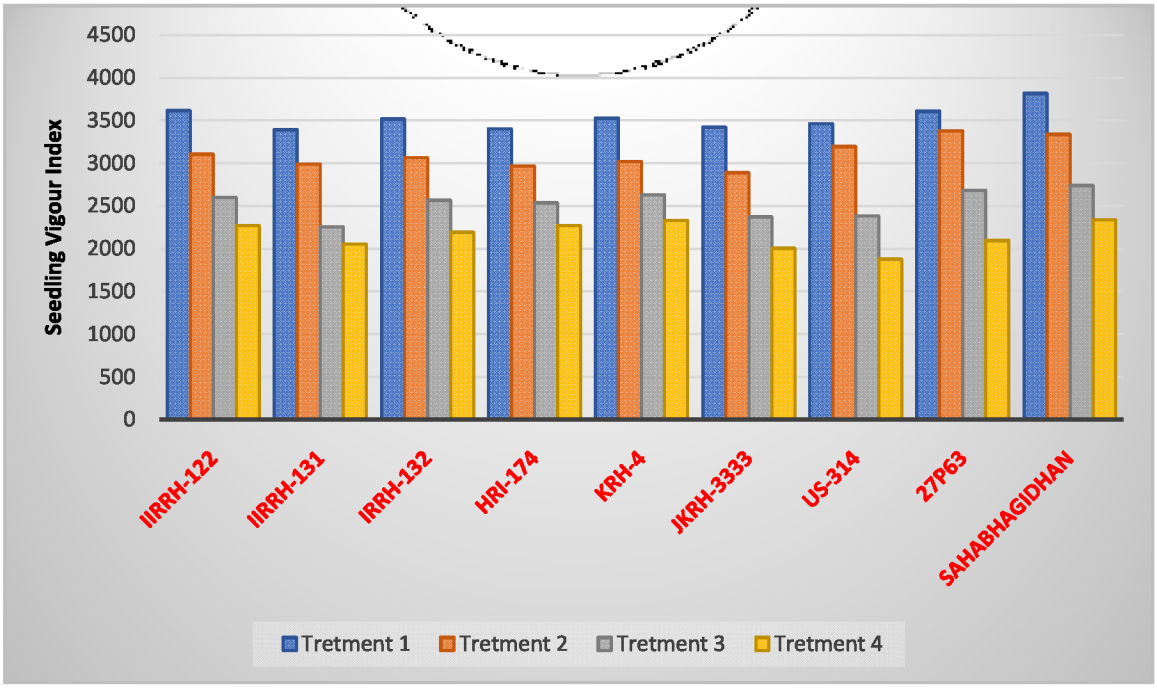


Fig. 4.7.1 Influence of Silicon on Seedling Vigour of rice genotypes

(B) *In vivo* Studies:

4.8 Symptomatology of Leaf Blast *(Pyricularia grisea)*

Leaf blast of rice caused by *Pyricularia grisea*may infect rice from the seedling stage to grain filling stage however, the disease usually develops during tillering stage (nodal blast) seedling to panicle initiation stage (leaf blast) and at heading stage (neck blast).Most of the plant parts are susceptible to infection except the roots. The initial infections started as small water-soaked areas on young leaves and enlarge into diamond shape with a blue gray colour in the center. Lesions often dry out and turn tan with a brown border at advance stage of disease development.

The symptomatology studies of the tested cultivars were carried out in the field as well as in laboratory under natural and artificial condition. The meteorological factors viz. Rainfall played a vital role in appearance of diseases. The observations of symptom and disease severity at different stages after sowing were recorded and varietal response against disease wasstudied.

The first appearance of leaf blast disease incidence was noted in cultivars 27P63 and HRI 174 at 45 DAS and found to be highly susceptible for the disease

4.9 Reaction of genotypes against leaf blast of rice

Table 4.9.1 Disease Scoring and Grouping of rice genotypes against leaf blast of rice

Reaction	Genotypes	Disease score
Resistant	US314, 27P63	3-4
Moderately resistant	IIRRH122, IIRRH131 and SAHABHAGI DHAN	4-6
Susceptible	HRI174, KRH4 and IIRRH132	6-7

Nine genotypes of rice (Table 4.9.1) were evaluated against leaf blast of rice under natural conditions using 0-9 IRRI scale for the assessment of disease reaction .The data indicate that two genotypes namely US314 and 27P63 exhibited resistant reaction ranging from 3 to 4 disease score whereas, genotypes IIRRH122, IIRRH131and Sahabhagi dhan showed moderately resistant reaction (4 to 6 score) and HRI 174, KRH4 JKRH3333 and IIRRH132 exhibited susceptible reaction under field study

4.10 Influence of Silixol on apparent infect rate (r/unit/day) and Area under disease progress curve (AUDPC) of rice genotypes under drought and irrigated conditions.

Influence of Silixol @ 0.6% was evaluated in drought and irrigated conditions against nine genotypes of rice and compared with untreated check in both the ecology. The Silixol application @ 0.6% foliar spray was applied at four different growth stages ie. tillering, PI, 50% flowering and milky grain stages and disease incidence were recorded accordingly (Table 4.10.1). The data indicate that among the treatments, application of Silixol under drought condition significantly reduced the Apparent infection rate (r/unit/day) in comparison to application of Silixol under irrigated condition. It was also observed that apparent infection rate was low in drought condition as compared to irrigated condition under untreated check. In regard to genotypic reaction against leaf blast of rice it varied significantly. In regard to r/unit day the most promising genotypes were HRI174 (0.011), 27P63(0.021), Sahbhagidhan (0.039), JKRH3333(0.040) in comparison to other tested genotypes under drought conditions where Silixol was applied. These genotypes were exhibited superior in relation to apparent infection rate values which were recorded lower and shown resistant reaction against the disease .Whereas, the genotypes recorded highest values of r/unit /day in HRI (0.114) , 27P63(0.133) Shahbhagidhan (0.054) and JKRH3333(0.110) under drought conditions where Silixol was not applied. The data reveals that under irrigated ecology the apparent infection rate was comparatively high where Silixol was not applied in comparison to Silixol applied treatment. However, drastic reduction in apparent infection rate was recorded under Silixol treatment under natural infection of leaf blast of rice in the irrigated ecology.

In regard to Area Under Disease Progress Curve (AUDPC) (Table 4.10.1) is concerned the data indicate that values are comparatively high under untreated check in comparison to Silixol treatment in both ecologies. However, the genotypes variability exhibited their reaction in the study .Among the tested genotypes the maximum values were recorded in JKRH3333 (179.7), HRI174 (177), KRH4 (167.8) and IRRH132 (144.5) over treated with Silixol JKRH3333 (109.8),HRI174 (140.2), KRH4(120.4) and IRRH132 (107.2) respectively where the AUPDC was drastically reduced under study. Thus, it may be summarised that AUDPC may be decreased after the application of Silixol in drought as well as irrigated ecology for combating the disease progress under study.

In regard to percent disease index (PDI) (Table 4.10.1) the data indicate that it may varied ranging from 4.22 to 41.77% in the genotypes evaluated in drought and irrigated ecology in different treatments. It is obvious from the data that maximum PDI 41.77 % was recorded in HRI 174 followed by JKRH3333 (38.44%) and KRH 4 (27.65%) in irrigated conditions in untreated check whereas, it was substantially reduced after the application of Silixol HRI (39.09%) ,KRH4 (30.44%) and JKRH3333 (28.77%) respectively in irrigated ecology . It is obvious from the data that PDI was comparatively low in the genotypes tested in drought conditions under untreated check and Silixol treatment over irrigated ecology.

Thus, it may be summarized that leaf blast disease severity may be minimized in the susceptible genotypes after the application of Silixol in both the ecology for their effective management and combat the economic losses .This is a very good alternative technology to manage the most devastating disease which may cause severe devastation to the crop and play a significant role for reducing application of fungicides for the management of disease. This may play a significant role for decreasing the environmental pollution due to chemical hazards and safe the environment in rice growing areas.

Table 4.10.1 Apparent infection rate, area under disease progress curve and percent disease index of rice genotypes for leaf blast under drought and irrigated conditions.

Treatment	Entries	Apparent infection rate (r/unit/day)				AUDPC	Percent Disease Index (PDI) %
		43-53 DAYS	53-63 DAYS	63-73 Days	Mean		
T1 (Control: Irrigated)	IIRRH-122	0.065	0.072	0.085	0.074	114.4	18.33
	IIRRH-131	0.054	0.067	0.093	0.071	129.6	15.0
	IRRH-132	0.056	0.066	0.087	0.069	134.5	18.22
	HRI-174	0.106	0.109	0.116	0.110	178.0	41.77
	KRH-4	0.099	0.101	0.107	0.102	165.8	27.65
	JKRH-3333	0.098	0.121	0.141	0.108	181.7	38.34
	US-314	0.034	0.041	0.057	0.044	87.6	9.89
	27P63	0.051	0.063	0.072	0.062	91.5	6.54
	SAHABHAGIDHAN	0.058	0.044	0.041	0.047	97.0	8.01
Mean		**0.076**	**0.080**	**0.088**	**0.080**	**131.12**	**20.41**
T2 (Irrigated + 0.6% Silixol)	IIRRH-122	0.099	0.051	0.033	0.061	135.7	12.6
	IIRRH-131	0.031	0.021	0.038	0.036	111.7	14.34
	IRRH-132	0.121	0.061	0.043	0.075	147.2	17.43
	HRI-174	0.102	0.131	0.108	0.113	201.0	39.09
	KRH-4	0.109	0.123	0.141	0.124	150.1	30.44
	JKRH-3333	0.106	0.117	0.121	0.119	177.0	28.77
	US-314	0.031	0.021	0.013	0.021	77.2	5.65
	27P63	0.022	0.041	0.054	0.039	85.1	4.22
	SAHABHAGIDHAN	0.042	0.046	0.048	0.045	94.1	5.76
Mean		**0.066**	**0.068**	**0.070**	**0.070**	**128.45**	**17.58**
T3 (Drought + 0.6% Silixol)	IIRRH-122	0.055	0.063	0.067	0.061	105.7	13.22
	IIRRH-131	0.058	0.031	0.038	0.042	95.8	16.13
	IRRH-132	0.031	0.055	0.049	0.045	107.2	22.11
	HRI-174	0.093	0.127	0.135	0.011	140.2	40.87
	KRH-4	0.042	0.041	0.043	0.042	120.4	.37.01
	JKRH-3333	0.082	0.023	0.017	0.040	109.8	32.46
	US-314	0.042	0.046	0.048	0.045	101.1	8.21
	27P63	0.028	0.020	0.017	0.021	87.10	4.44
	SAHABHAGIDHAN	0.023	0.041	0.054	0.039	89.17	7.23
Mean		**0.049**	**0.051**	**0.056**	**0.067**	**107.07**	**13.08**

T4 (Control: Drought)	IIRRH-122	0.058	0.065	0.093	0.072	112.4	18.33
	IIRRH-131	0.045	0.049	0.052	0.048	122.6	22.02
	IRRH-132	0.075	0.065	0.055	0.065	144.5	21.23
	HRI-174	0.106	0.117	0.121	0.114	177.0	39.77
	KRH-4	0.099	0.114	0.158	0.201	167.8	36.11
	JKRH-3333	0.098	0.101	0.131	0.110	179.7	31.67
	US-314	0.058	0.012	0.051	0.031	78.6	9.83
	27P63	0.056	0.027	0.018	0.033	93.5	5.41
	SAHABHAGIDHAN	0.068	0.054	0.040	0.054	102.0	11.01
Mean		**0.072**	**0.076**	**0.079**	**0.076**	**130.9**	**21.70**
CD (0.05%)		0.65	0.427	0.839	0.921	1.37	1.69

4.11 Effect of Silixol on morphophysiological parameters of rice genotypes under drought and irrigated conditions

4.11.1 Plant Height, Leaf area index (LAI), No of Tillers/Plants, Relative Water Content (RWC) and Membrane Stability Index (MSI)

Plant Height: The effect of 0.6% Silixol on plant height (Table 4.11.1) was compared with two different conditions (ie., irrigated and drought) and it was found that 0.6% Silixol application increased plant height in all the nine genotypes in both the conditions. The maximum percent reduction in plant height was recorded under drought condition (6.9%) as compared to irrigated condition. It is obvious from the table that plant height was comparatively increased by the application of Silixol in both irrigated and drought conditions. The maximum percent increase in plant height was recorded in drought condition under applied Silixol in the genotypes IRRH132, (6.3%), 27P63 (5.2%) and KRH4 (5.0%) over irrigated condition where HRI174 (3.9%), IRRH132 (3.3%) and IRRH131 (3.3%) maximum percent increase was recorded. However, minimum percent increase in plant height was exhibited by the genotypes JKRH3333 (0.8%) under irrigated conditions and HRI 174 (2.4%) in drought conditions.

Leaf area index: It was measured in both ecology in the tested genotypes under study. It is obvious from the data (Table 4.11.1) that the genotypes varied in the both ecology after the application of Silixol. However, the superiority of genotypes was recorded in irrigated conditions under Silixol as compared to drought conditions. The genotypes that had shown high leaf area index were IIRRH131(7.79) followed by JKRHJ3333 (7.60), IIRRH131(7.58) and US 314(7.33) under irrigated Silixol application whereas, minimum leaf area was recorded inKRH4(4.19),JKRH3333(5.27) and IIRRH122(5.30) under drought condition.

Tillers number per plant: The data (Table4.11.1) indicate that application of Silixol @ 0.6% did not much influenced the tillers number per plant under irrigated condition. However, it was significantly increased tillers number per plant in all nine tested genotypes under drought condition over untreated check. Maximum number of tillers per plant was recorded in 27P63 (13) followed by Sahabhagidhan (12), HRI 174(12) and US 314 (11) under drought condition with the 0.6% Silixol application, whereas, under drought condition same genotypes gave 7, 9, 8 and 9 tillers number per plant respectively.

Relative Water content: The data presented in Table (4.11.1) reveal that the relative water content (%) in the leaves of the nine experimental genotypes decreased significantly under drought condition compared with irrigated condition. Application of Silixol @ 0.6% significantly increased the RWC in almost all tested genotypes under both the conditions. Among the tested genotypes, maximum percent increase in RWC in response to 0.6% Silixol was recorded in genotypes, JKRH 3333 (8.6%), IRRH 132 (5.9%) and IIRRH 131(3.7%) under irrigated condition over without application of Silixol under irrigated condition. However, maximum percent increase in RWC in response to 0.6% Silixol under drought condition was recorded in genotypes, KRH 4 (8.5%), 27P63 (7.2%), Sahbhagidhan (7.4%) and US 314 (5.7%) as compared to only drought condition.

Membrane stability index (MSI): Data presented in regard to membrane stability index (MSI)in table 4.8.2 indicate that drought condition significantly reduced the MSI of leaves of all tested genotypes, data shows that average mean value of MSI under irrigated condition is 84% and 70% was recorded under drought condition. Application of Silixol @0.6% increases significantly MSI of leaves of all tested genotypes under drought condition. Maximum percent increase was recorded in genotypes, 27P63 (14.5%) followed by Sahbhagidhan (9.4%), IRRH 132 (8.3%) and KRH 4 (4.3%) under drought condition with the application of 0.6% Silixol as compared to drought ones.

Table 4.11.1: Influence of silicon on morpho-physiological parameters of rice genotypes

Treatment	Entries	Plant height (cm)	Leaf area index (LAI)	No. of Tillers /Plant	Relative water content (RWC %)	Membrane Stability Index (MSI)
T1(Control)	IIRRH-122	124	6.24	11	81	77
	IIRRH-131	120	6.58	12	85	81
	IRRH-132	122	6.26	13	87	82
	HRI-174	129	6.64	12	86	82
	KRH-4	130	5.32	11	81	77
	JKRH-3333	122	6.47	11	81	76
	US-314	126	6.69	12	87	83
	27P63	125	5.71	12	88	83
	SAHABHAGIDHAN	117	5.26	13	84	79
Mean		**124**	**6.13**	**12.0**	**84**	**80.1**
T2 (Irrigated + 0.6% Silixol)	IIRRH-122	128	7.16	12	84	79
	IIRRH-131	124	7.79	11	90	87
	IRRH-132	126	7.58	9	89	86
	HRI-174	134	6.83	10	87	86
	KRH-4	133	6.28	14	81	77
	JKRH-3333	123	7.60	12	88	89
	US-314	130	7.33	12	85	80
	27P63	127	6.59	9	87	82
	SAHABHAGIDHAN	121	6.39	12	85	80
Mean		**127**	**7.06**	**11.2**	**86**	**82.9**
T3 (Drought + 0.6% Silixol)	IIRRH-122	118	5.31	11	80	77
	IIRRH-131	114	6.21	10	72	69
	IRRH-132	119	5.90	11	68	65
	HRI-174	129	5.05	12	68	65
	KRH-4	127	5.34	11	77	72
	JKRH-3333	121	6.53	10	68	65
	US-314	124	6.58	11	74	70
	27P63	121	5.41	13	74	71
	SAHABHAGIDHAN	114	6.63	12	73	70
Mean		**121**	**5.89**	**11.3**	**73**	**69.1**

T4 (Drought)	IIRRH-122	115	5.30	8	78	75
	IIRRH-131	110	5.52	10	71	67
	IRRH-132	112	5.36	9	67	60
	HRI-174	126	5.37	8	67	64
	KRH-4	121	4.19	9	71	69
	JKRH-3333	118	5.27	9	66	63
	US-314	119	5.39	9	70	69
	27P63	115	6.07	7	69	62
	SAHABHAGIDHAN	110	5.30	9	68	64
Mean		**116**	**5.31**	**8.7**	**70**	**65.7**
CD (0.05%)	Factor(A)	1.598	0.890	1.178	2.341	0.772
	Factor(B)	2.149	0.342	N/A	2.204	1.004
	Factor(B)at same level of A	N/A	0.777	N/A	4.591	2.055
	Factor(A)at same level of B	N/A	1.093	N/A	4.751	2.039

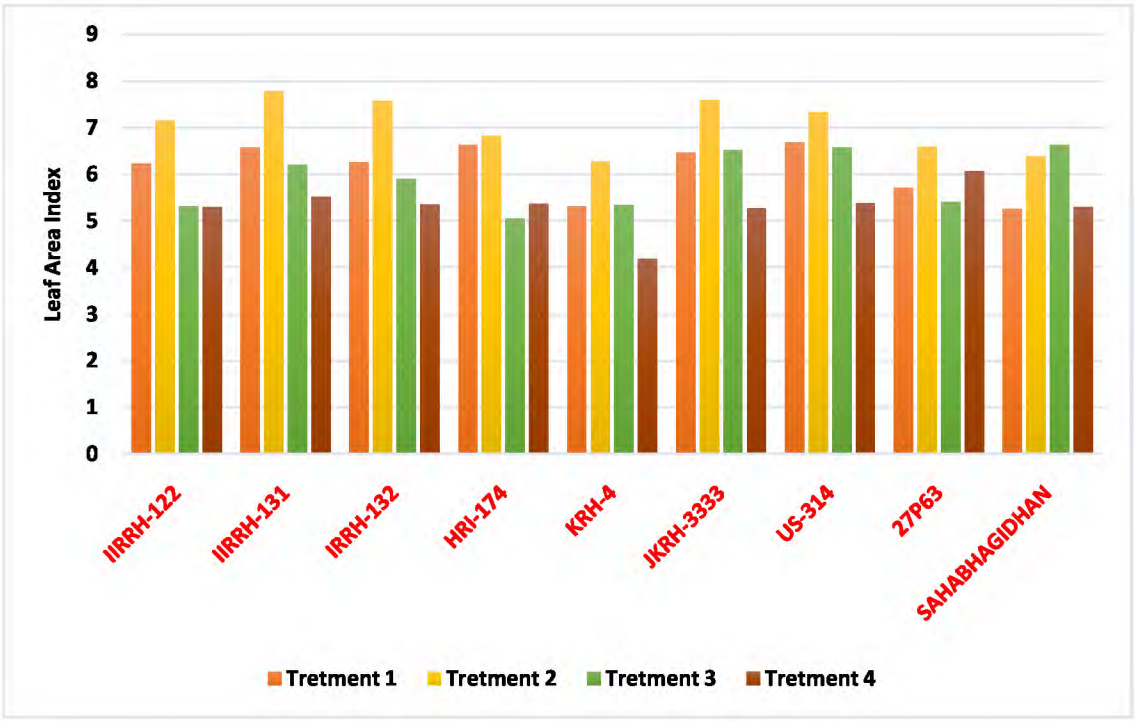


Fig. 4.11.1 Influence of Silicon on Leaf Area Index of rice genotypes

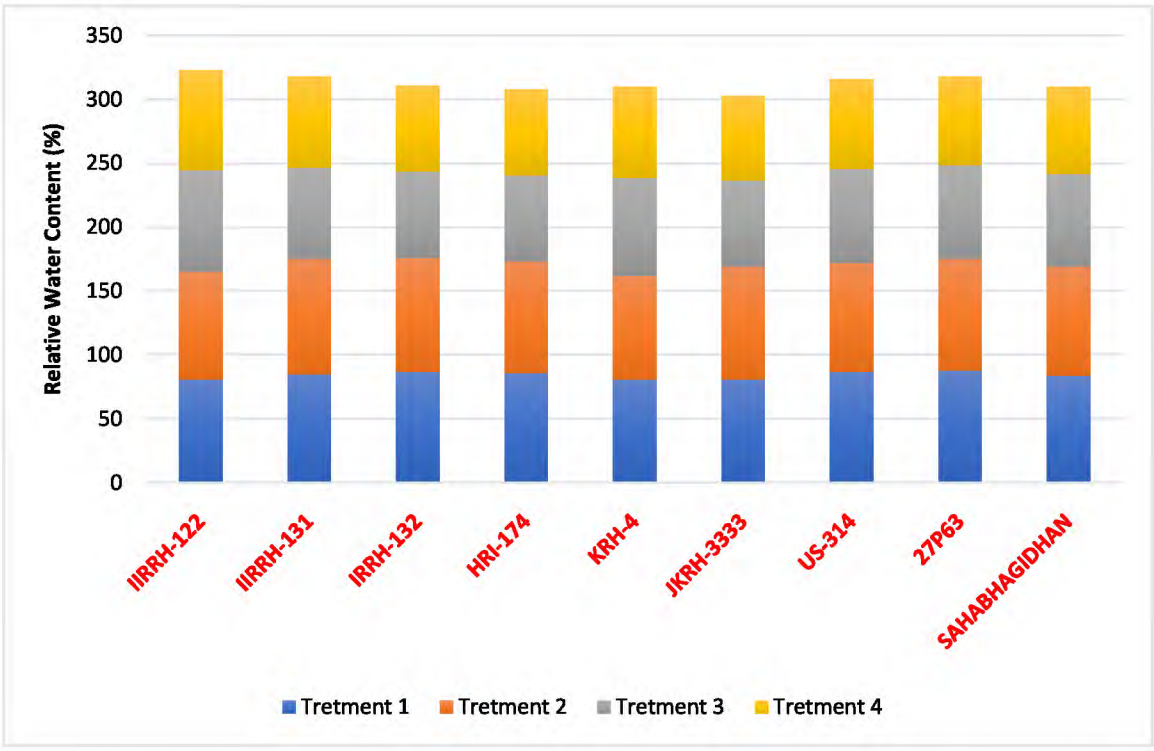


Fig. 4.11.2 Influence of Silicon on Relative Water Content (RWC) of rice genotypes

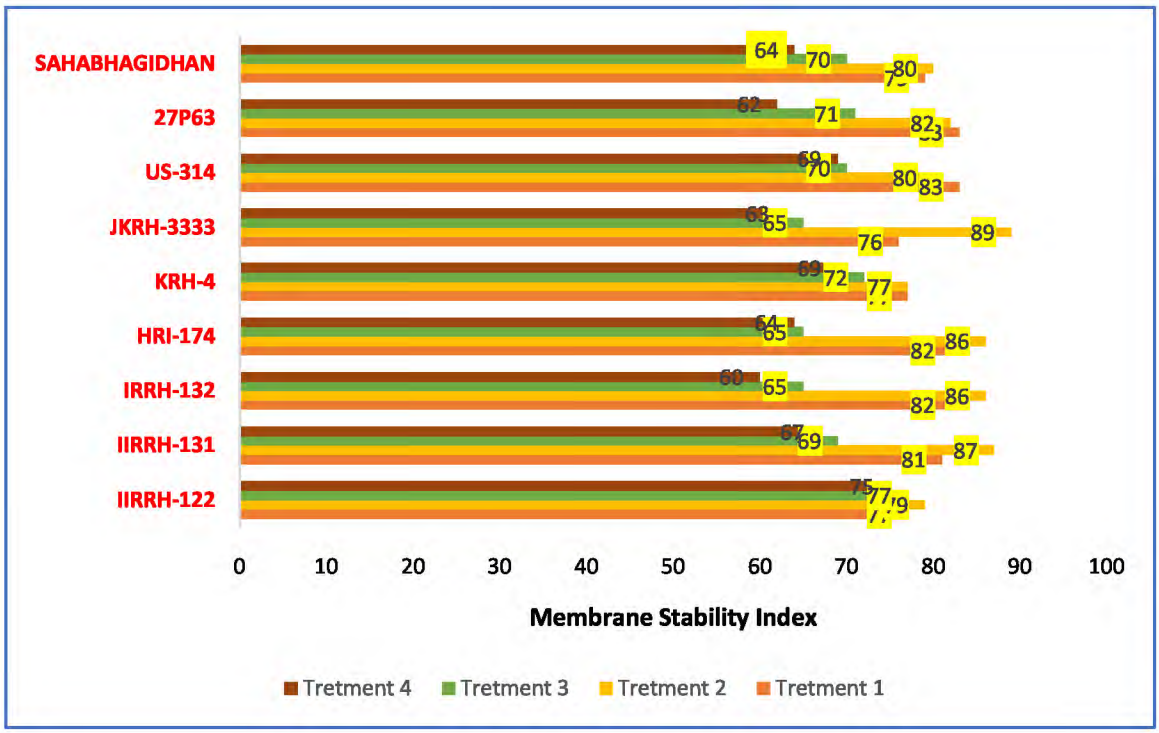


Fig. 4.11.3 Influence of Silicon on Membrane Stability Index (MSI) of rice genotypes

Transplanting of Rice

Rice Field

Symptoms of leaf blast of rice

Observation recorded (Shoot length)

A view of monitoring of Field experiments

4.12 Effect of Silixol on yield and yield attributing traits of rice genotypes under drought and irrigated conditions

In regard to **Total dry matter** (Table 4.12.1) it is clear from the data that genotypes varied drastically in the irrigated and drought condition. Total dry matter (g/m^2) was reduced in all nine genotypes under drought condition. It was noted that 0.6% Silixol application increased Total dry matter (g/m^2) in all genotypes in both the conditions (irrigated and drought). Among the tested genotypes, maximum percent increase in total dry matter (g/m^2) was recorded in genotypes, HRI 174 (15.1%), IIRRH 131(15.6%), IIRRH 132 (15.6%) and 27P63 (13.2%) under irrigated condition with the application of 0.6% Silixol over irrigated only . However, maximum percent increase in total dry matter (g/m^2) was recorded in genotypes, Sahabhagidhan (25.0%), JKRH 3333 (23.2%) and IIRRH 131(22.0%) under drought condition with the application of 0.6% Silixol over drought only.

Data presented in table (4.12.1) indicate that **Number of panicle/plants** is one of the important trait, which was recorded at flowering stage and it was significantly affected by water regime. The mean of almost tested genotypes was reduced by >14% under drought treatment in comparison with irrigated control. The maximum percent increase in panicle number per plant was recorded in the tested genotypes, JKRH 3333 (40.0%), HRI 174 (33.3%), 27P63 (28.6%) under drought condition with the application of 0.6% Silixol in comparison with drought control.

In regard to **Number of grain/panicles**, data depict in (Table 4.12.1) shows that number of grains per panicle is very important yield related trait which show significant change in drought condition. Drought (T4) significantly reduced the grain number per panicle in tested genotypes in comparison with irrigated ones. Application of Silixol to drought stressed crop (T4) significantly reversed negative effects of water. Maximum grains number per panicle was recorded in genotypes, US 314 (136.0), HRI 174 (132.0), 27P63 (130.7) and JKRH 3333 (130.7) under drought condition with the application of 0.6% Silixol (T3) in the comparison with drought only.

In regard to **1000 weight**, data shows in (Table 4.12.1) indicate that the mean of 1000 grain weight was significantly affected in the drought condition in comparison with the irrigated ones. However, imposing drought

stress (T4) after flowering stage the mean percent reduction in 1000 grains weight was 16.8% in comparison with irrigated treatment. Application of Silixol on drought stressed crop (T4) resulted in significantly reversed the deleterious effect of drought stress and maximum 1000 grains weight was recorded in genotypes, US 314 (21.1 g), KRH 4(21.0 g), Sahabhagidhan (20.6 g) and IRRH 132 (20.1 g) in comparison with drought only (T4).

In regard to **Grain Yield (q/ha)**, data reveals in (Table 4.12.1) that drought stress (T4) greatly influence the grain yield in all nine genotypes in comparison with irrigated condition (T1). It was noted that the mean reduction percent in grain yield is 27% under drought stress (T4). However, Application of Silixol resulted increase in grain yield in the both treatments irrigated as well as drought condition in comparison with their control ones. Maximum grain yield was recorded in genotypes, US 314 (101 q/ha), 27P63 (99 q/ha), HRI (99 q/ha) and KRH 4 (91 q/ha) under irrigated condition with 0.6% Silixol (T2) in comparison with their control ones (T1), whereas, maximum grain yield was recorded in these genotypes, US 314 (84 q/ha), 27P63 (82 q/ha), HRI (81 q/ha) and KRH 4 (71 q/ha) under drought condition with 0.6% Silixol (T3) in comparison with their control ones (T4).

Harvest index (HI) is one of the most important yield traits, which was measured after harvest. In regard to HI, Data depicts in (Table 4.12.1) indicate that HI is influenced by the drought stress, whereas response of Silixol application significantly increased HI in both the treatments irrigated as well as drought stress. Among the tested genotypes the mean of HI was recorded 47% in irrigated condition (T1) and 43% was recorded under drought stress condition (T4). It was noted that maximum percent increase in HI was recorded in genotypes, Sahabhagidhan (7.1%), IIRRH 122 (6.1%) and KRH 4 (2.5%) under drought with the application of 0.6% Silixol (T3) in comparison with the drought ones (T4), whereas, JKRH 3333 (20.0%), KRH 4 (15.9%), IIRRH 122 (15.4%) and Sahabhagidhan (14.3) genotypes showed maximum percent increase in HI under irrigated condition with the application of 0.6% Silixol (T2) in comparison with the irrigated only (T1).

Table 4.12.1: Influence of silicon on yield and yield attributing traits of rice genotypes.

Treatment	Entries	TDM g/m^2	No. of Panicle/ Plant	No. of grain/ Panicle	1000 grain wt (g)	Grain Yield (q/ha)	HI (%)
T1(Control)	IIRRH-122	1600	9	122.0	21.5	62	39
	IIRRH-131	1457	9	128.0	18.5	73	49
	IRRH-132	1496	10	123.0	21.1	71	49
	HRI-174	1641	8	136.3	18.1	85	54
	KRH-4	1726	7	125.7	22.4	77	44
	JKRH-3333	1526	9	137.0	18.6	62	40
	US-314	1615	12	143.0	22.7	88	55
	27P63	1588	7	133.0	17.1	86	54
	SAHABHAGIDHAN	1339	9	118.0	21.9	58	42
Mean		**1554**	**9**	**129.6**	**20.2**	**74**	**47**
T2 (Irrigated + 0.6% Silixol)	IIRRH-122	1665	10	128.7	23.3	75	45
	IIRRH-131	1685	9	131.3	18.2	86	51
	IRRH-132	1729	8	129.0	23.1	84	49
	HRI-174	1906	9	139.7	19.8	99	52
	KRH-4	1766	9	141.0	24.7	91	51
	JKRH-3333	1580	8	132.0	20.2	75	48
	US-314	1791	11	147.3	24.2	101	57
	27P63	1798	7	149.0	18.0	99	55
	SAHABHAGIDHAN	1480	9	121.0	23.2	70	48
Mean		**1629**	**9**	**135.4**	**20.9**	**87**	**49**
T3 (Drought + 0.6% Silixol)	IIRRH-122	1568	7	112.0	19.9	57	35
	IIRRH-131	1443	7	121.0	16.0	69	45
	IRRH-132	1416	9	115.3	20.1	67	45
	HRI-174	1553	8	132.0	16.3	81	50
	KRH-4	1678	8	120.3	21.0	71	41
	JKRH-3333	1497	7	130.7	17.4	57	36
	US-314	1561	8	136.0	21.1	84	51
	27P63	1552	9	130.7	16.3	82	50
	SAHABHAGIDHAN	1321	8	113.0	20.6	42	30
Mean		**1592**	**8**	**123.4**	**20.2**	**68**	**43**
T4 (Drought)	IIRRH-122	1311	8	110.0	18.7	42	33
	IIRRH-131	1183	10	117.7	14.6	54	45
	IRRH-132	1162	9	109.0	17.2	52	46
	HRI-174	1287	6	128.3	15.8	65	51
	KRH-4	1411	7	117.0	17.1	57	40
	JKRH-3333	1215	5	123.7	16.1	44	36
	US-314	1309	8	129.7	18.8	70	54
	27P63	1300	7	126.7	14.7	67	51
	SAHABHAGIDHAN	1057	8	100.0	18.4	30	28
Mean		**1248**	**8**	**118.0**	**16.8**	**54**	**43**
CD (0.05%)	Factor(A)	54.572	0.433	6.362	0.623	1.84	0.984
	Factor(B)	51.237	0.981	6.874	1.492	3.52	2.827
	Factor(B)at same level of A	106.769	1.978	N/A	N/A	N/A	5.683
	Factor(A)at same level of B	110.527	1.898	N/A	N/A	N/A	5.417

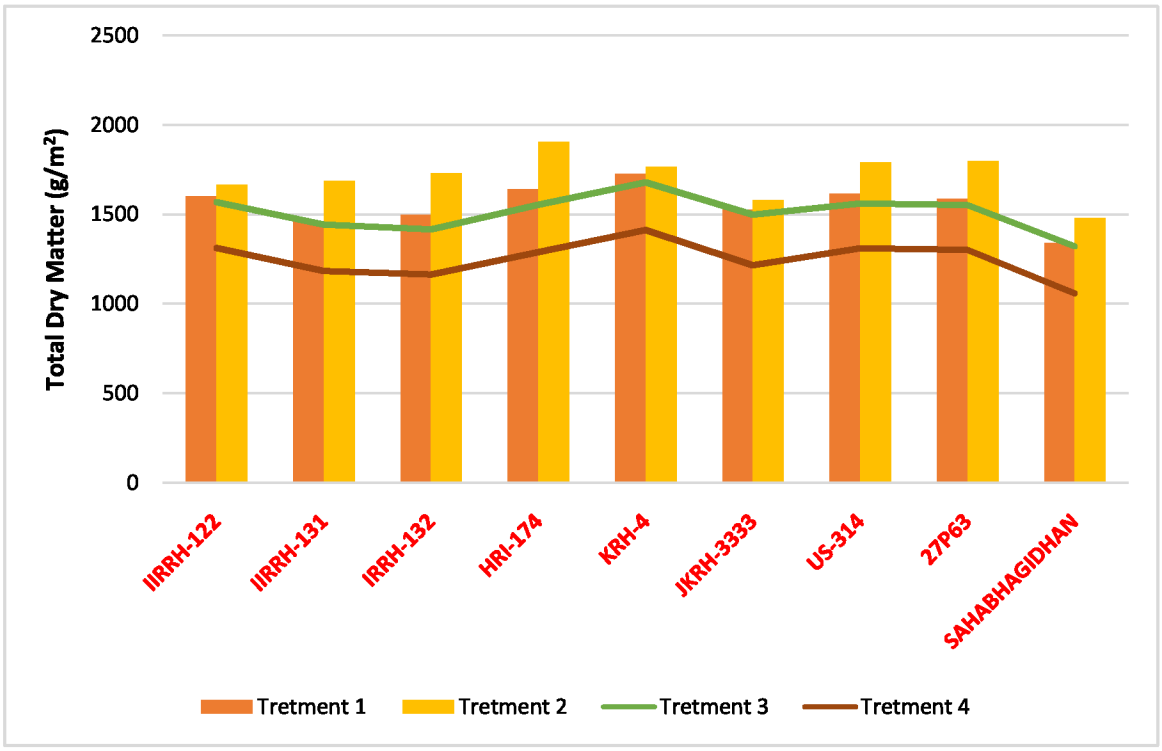


Fig. 4.12.1 Influence of Silicon on Total Dry Matter (g/m^2) of rice genotypes

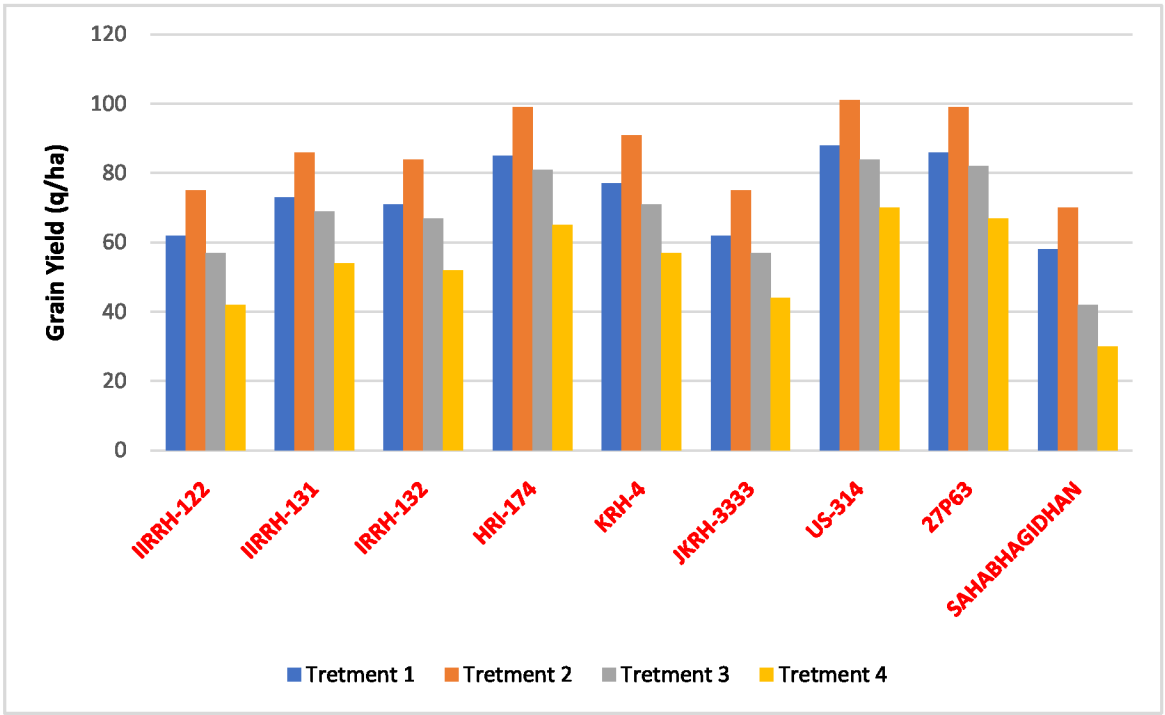


Fig. 4.12.2 Influence of Silicon on Grain Yield (q/ha) on rice genotypes

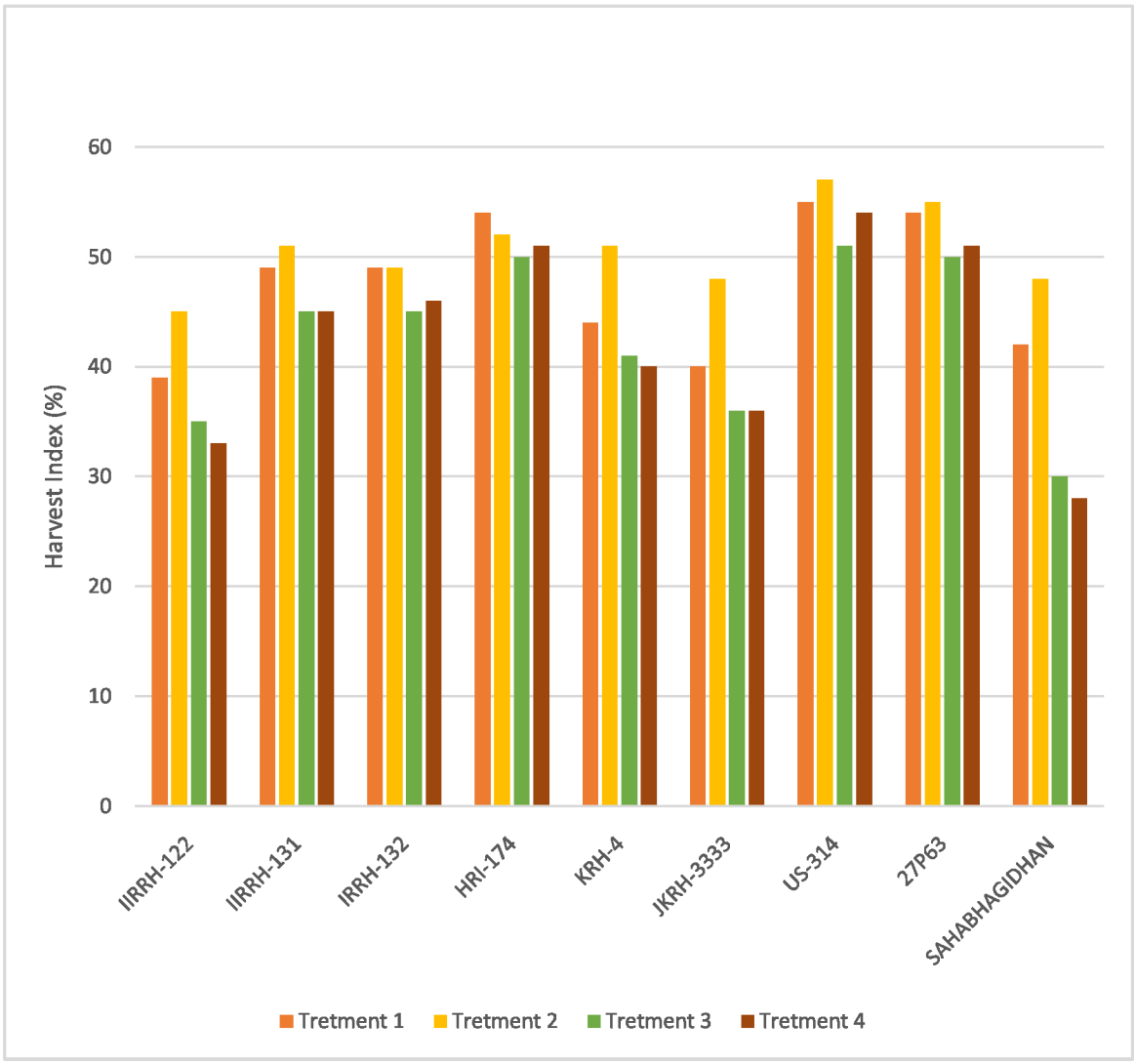


Fig. 4.12.3 Influence of Silicon on Harvest Index (%) of rice genotypes

Chapter -V

DISCUSSION

DISCUSSION

Rice is the most important staple food crop consumed by nearly half of the world population. It is grown in India in diverse ecosystems and ranked next to China in production in the world. In the recent year unstable rice production has been noted due to various abiotic and biotic stresses.

The Indian economy has shown a great imbalance in agriculture sector due to fluctuation in productivity of rice. Although, rice has shown a wide adaptability in different agro climatic condition under irrigated and rain fed ecosystem but the annual productivity is increasing due to adoption of improved agricultural practice.

In Madhya Pradesh, several production constraints have been identified in rice production. Among the biotic stresses, the occurrence of leaf blast is appearing and increasing at an alarming rate in the region, which may cause considerable yield losses to the crop.

The use of chemical fungicides are the primary tools for combating the economic losses due to disease incidence, but their residual effect is causing chemical hazards which may cause the soil, water and environmental pollution.

The present investigation is based on evaluation of bio-pesticides along with chemical fungicides, their efficacy and factors in controlling the leaf blast of rice.

After adopting eco-friendly approaches for managing leaf blast disease of rice in Kymore plateau and Satpura Hills of Madhya Pradesh and in the context of reviews presented in the previous chapter, the experimental findings are discussed below.

5.1 Influence of culture media on mycelial growth (mm) of *Pyricularia grisea*

Pyricularia grisea shows maximum growth in Oat Meal Agar and Potato Dextrose Agar medium with traces of sporulation. These findings are supported

by Hau and Rush, (1980) who observed that Oat Meal Agar and Potato Dextrose Agar induces abundant conidial production of *Pyricularia grisea*, followed by 12hrs of darkness. Similar observations were also recorded by Arshad *et al.* (2013) on *Pyricularia grisea*. These findings are also in accordance with the observation recorded by Cruz *et al.* (2009).

5.2 Influence of Temperature on mycelial growth (mm) of *Pyricularia grisea* in Potato Dextrose Agar medium

Pyricularia grisea shows maximum growth at 25°C temperature in Potato Dextrose Agar medium with traces of sporulation. As the temperature increase 35°C, it reduces the growth and sporulation. Similar observations were recorded by Awoderu *et al.* (1991), Okeke *et al.* (*1992*) on *Pyricularia grisea*. They reported the favorable temperature for the growth and sporulation of *Pyricularia grisea* in the range of 20°C and 30°C. Studies revealed that with an increase or decrease in the temperature from the ambient of 30°C, there was a study decrease in the growth ability of *Pyricularia grisea*.

5.3 Influence of pH on mycelial growth (mm) and sporulation of *Pyricularia grisea*

Pyricularia grisea shows maximum growth in Potato Dextrose Agar medium with traces of sporulation in pH-6 and pH-5 in Potato Dextrose Agar amended medium. As the pH decreases the growth and sporulation reduce due to alkaline medium requirement for pathogenic fungi. The pH of the medium was changed up to 5 and 6 during the growth of the fungus (Thomas 1940 and Ramakrishanan,1948).

5.4 Influence of Silixol on mycelial growth (mm) and sporulation of *Pyricilaria grisea*

Four different concentrations of Silixol@0.3%, 0.6%, 0.9% and 1.2% were evaluated against *Pyricularia grisea* in different period of incubation for the assessment of mycelial growth and Sporulation in Potato Dextrose agar medium and compared with standard fungicide Carbendazim 50WP@0.1% over untreated check. Among the treatment, Silixol@0.9% gave optimum mycelia growth

(59.3mm) followed by Carbendazim (56.6mm) over Control (67.9mm). It was noted that minimum mycelial growth was observed in Silixol@0.6% (32.4 mm) at 144 hrs of incubation over standard fungicide check Carbendazim (36.6mm) and untreated check(77.9mm) .None of the Silixol sources induced the sporulation of *Pyricularia grisea.* except Silixol@0.6% where sporulation was observed in traces.

5.5 Studies on disease resistance in rice cultivars against Leaf blast of rice.

Percent disease index (PDI) is indicate that it may varied ranging from 42.25 to 41.77% in the genotypes evaluated in drought and irrigated ecology in different treatments. It is obvious from the data that maximum PDI 41.77% was recorded in HRI174 followed by JKRH3333 (38.44%) and KRH4 (27.65%) in irrigated conditions in untreated check whereas, it was substantially reduced after the application of Silixol HRI174 (39.09%), KRH4 (30.44%) and JKRH3333 (28.77%) respectively in irrigated ecology. It is obvious from the data that PDI was comparatively low in the genotypes tested in drought conditions under untreated check and Silixol treatment over irrigated ecology. Epidemiological observations regarding Leaf blast showed that the disease appeared 40-45 days after germination. The disease expands swiftly during 70 to 80 days crop stage, when temperature was between 18^0C to 20^0C. Low rainfall and low moisture content had favored `the incidence of Leaf blast disease.

These results are identical with the findings of Chakraborti and Wilcoxson (1970), Chakrabarti (1971), Suzuki (1974). They observed that the maximum frequency of rainy days and minimum temperature ranged from 22^0C to 22.9^0C during the early growth stage, were conducive to blast development. Haung *et al.* (1980) noted that night temperature below 20^0C or less may influence the blast development considerably. Similar finding were also repoted by Yoshino (1979) and Rahanema (1979) who noted that high humid condition, free water, low night temperature favorable for prolonged leaf penetration of pathogen. These results are in accordance with the findings of Murlidharan and Venkat Rao (1980) who studied forecasting epidemic outbreak in the planes on the basis of atmospheric condition. The present findings are also supported with the results obtained by Tripathi *et.al.*(1997).

5.6 Influence of Silicon on yield attributing characters

The susceptible cultivars HRI174. KRH4, IIRRH132 and JKRH3333 exhibited maximum plant height, number of tillers and minimum panicle length and yield. Whereas panicle length and yield were recorded maximum in resistant cultivars US314, 27P63, IIRRH121, IIRRH131 and Sahbhagidhan. These findings are also in accordance with the observation recorded by Magar (2015).The local susceptible cultivars HRI174, KRH4, IIRRH132 and JKRH3333 exhibited maximum plant height, number of tillers and minimum panicle length and yield. The plant height and number of tillers are more in susceptible cultivars and panicle length and yield are found maximum in resistant cultivars US314, 27P63, IIRRH121, IIRRH131 and Sahbhagidhan.

5.7 Effect of Silixol on morphophysiological parameters of rice genotypes under drought and irrigated conditions

In present investigation, morphophysiological parameters (germination, root length, shoot length, seedling vigour (*In vitro*) plant height, leaf area index, number of tillers per plant, relative water content, membrane stability index, total dry matter and yield (*In vivo*) were examined during different growth stages, the results on which are being interpreted below:

Germination (%)

Seed germination is the most essential fundamental and vital phases in the growth cycle of plants that determine plant establishment and the yield of the crops. Germination were recorded in US-314(89%), Sahabhagidhan (89%), JKRH3333 (88%) and KRH-4(88%) under irrigated conditions whereas, under drought condition these genotypes showed 68%, 71%, 72% and 79% respectively. The reduction in germination under drought stress might be due to an osmotic effect. It may also affect the many common reactions in plants and leads to cellular dehydration which causes osmotic stress and removal of water from the cytoplasm into the extracellular space. Similar results were reported by Dahanayake *et al.* (2015) in mung bean and supported the present findings

Silicon (Si) has been widely reported to have beneficial effect on mitigating drought stress in plants. It was observed that 0.6% Silixol increases the germination percentage under drought condition. It was also observed that Silixol application decrease the germination percentage due to excess moisture under irrigated condition. Among the tested genotypes, the maximum increased germination percentage were recorded in US-314 (19.1%), 27P63 (19.1%), JKRH3333 (15.1%), SAHABHAGIDHAN (14.1%) and HRI-174(11.0%) under drought + 0.6% Silixol (T3) over drought untreated check (T4). These results are in accordance with the findings reported by Phurailatpa Pooja Sharma and Sahadevan Jawahar (2019).This may be explained on the basis of the fact that Increased germination under Silixol application might be due to seed soaking with silicon through Silixol plus enhanced the cell extension through formatting Si-polyphenol complexes and lignin which caused loosening of cell wall as a resulting the increase in higher germination percentage.

In regard to Root length and shoot length, the tested genotypes, 27P63 (15.0 cm), KRH-4(14 cm) US-314(14.0 cm) and IRRH-132(13.0 cm) showed maximum root length, whereas, maximum shoot length was recorded in genotypes, IRRH132(18.0 cm), 27P63 (18.0 cm) and US-314(16.0 cm) under drought condition with the application of 0.6% Silixol over drought only. These results are in agreement with the results reported by. Jawahar *et al.* (2015) in which he was stated that application of Silixol granules increased the root length and shoot length .Similar results were also obtained by Yavarzadeh. *et al.* (2008) who reported that increase in plant height could be due to deposition of silica on the plant tissues causing erectness of leaves and stem.

Seed germination and seedling emergence are the most critical and sensitive stages in the life cycle of plants which may varied in the genotypes and influencing the seed viability. Therefore, seedling vigour study is having paramount importance for the superiority of genotypes for screening against abiotic and biotic stresses. In regard to Seedling Vigour, genotypes 27P63 (27.9%), US-314(27.0%), JKRH-3333(18.3%) and Sahabhagidhan (17.1%)

exhibited maximum values whereas, minimum percent increase seedling vigour index was recorded in IIRRH-131(9.8%), HRI-174(11.7%), KRH-4(12.9%) under drought condition with the application of 0.6% Silixol. Results from the present study showed that drought stress negatively affected Seedling Vigour which could be improved by the addition of Silixol, Results from the present study also indicated that during drought stress Silixol played a protective role in regard to seed germination. This ameliorative effect of Si may be due to its hydrophilic nature by protecting the plants from drought.

These results are in accordance with the findings reported by Sajitha Biju *et al*., 2017 who worked on lentil in which the seedling vigour were significantly improved by Si application. Many researchers have concluded that Si has positive effect on the physiology and metabolism of different plants against drought stress (Torabi *et al*., 2012; Ma and Yamaji, 2008; Liang *et al*., 2003) and supported the present findings.

Morphophysiological parameters and yield attributing traits:

In regard to plant height, It is obvious from the result that it was comparatively increased by the application of Silixol in both irrigated and drought conditions. The maximum percent increase in plant height was recorded in drought condition under applied Silixol in the genotypes IIRRH132, (6.3%), 27P63 (5.2%) and KRH4 (5.0%) over irrigated condition where HRI174 (3.9%), IIRRH 132 (3.3%) and IIRRH131 (3.3%) had recorded maximum percent increase over drought alone .These results are in agreement with the findings of Singh *et al.* (2005) who reported that different Silicon levels significantly increased plant height, dry matter production, panicles per m^2, filled grains per panicle, test weight and yield of rice. Jawahar and Vaiyapuri (2010) also recorded similar results with regard to application of Silixol which may increased the plant height in rice under both the conditions irrigated as well as drought and supported the present findings.

It was stated that drought trigger the inhibition of cell growth, leading to a reduction in leaf development. Lower leaf surface causes less water uptake from the soil and transpiration is reduced. In regard to leaf area index, it was

found that application of 0.6% Silixol showed positive effects on greater leaf area index under both the conditions. The genotypes that had shown high leaf area index were IIRRH131 (7.79) followed by JKRHJ3333 (7.60), IIRRH131(7.58) and US 314 (7.33) under irrigated Silixol application whereas, minimum leaf area was recorded in KRH4(4.19), JKRH3333(5.27) and IIRRH122(5.30) under drought condition. Larger leaf area and high chlorophyll content might have accumulated more photosynthesis and produce higher biological yield. These results are in agreement with the findings reported by Jawahar and Vaiyapuri (2010) and Singh et al (2005) who concluded that Si improves high interception of light by keeping leaves erect there by stimulating canopy photosynthesis in rice.

In regard to tillers per plant, maximum number of tillers was recorded in 27P63 (13) followed by Sahabhagidhan (12), HRI 174(12) and US 314(11) under drought condition with the 0.6% Silixol application, whereas, under drought condition same genotypes gave 7, 9, 8 and 9 tillers per plant respectively. Tillering is the production of expanding auxiliary bud which is clearly associated with nutritional condition of the mother clump because tillers receive carbohydrate and nutrients from the mother clump during early growth period and this was improved by silicon application. Similar findings have also been reported by Chanchareonsook *et al.* (2002) and Jawahar *et al.* (2015) and iang *et al.,* (1994) who reported that silicon significantly increased the number of tillers in rice.

Relative water content (RWC) of rice was also studied in the genotypes in drought and irrigated ecology with the application of Silixol. It was observed that most of the genotypes expressed low RWC in flag leaves under drought stress. However, the Silixol applied plants could maintain superior water status under drought stress compared with the control plants non silicon treatment under drought stress. These results indicate that Si application can improve the water status of rice in field under drought conditions. Among the tested genotypes, maximum percent increase in RWC in response to 0.6% Silixol was recorded in JKRH3333 (8.6%), IIRRH132 (5.9%) and IIRRH131 (3.7%) under irrigated condition over without application of Silixol under irrigated condition. However, maximum percent increase in RWC in response to 0.6% Silixol under drought

condition was recorded in genotypes, KRH4 (8.5%), 27P63 (7.2%), Sahbhagidhan (7.4%) and US314 (5.7%) as compared to only drought condition. These results are in conformity with the findings reported by Shen *et al.,* (2010) and Kobra Maghsoudi *et al*., (2016) who reported that Si may play a significant role to maintain the water balance despite the greater water loss by the plant leaf. Thus, it may be summarized that application of Si improves the water status of the stressed plants.

Drought impaired membrane stability by increasing electrolyte leakage. The integrity and functions of biological membranes are very sensitive to environmental stress and stress-induced damage to membranes. The present findings revealed that average mean value of MSI under irrigated condition was 84% whereas 70% recorded under drought condition. Application of Silixol @0.6% increased significantly MSI of leaves of all the tested genotypes under drought condition. Maximum percent increase of MSI was exhibited in 27P63 (14.5%) followed by Sahbhagidhan (9.4%), IRRH 132 (8.3%) and KRH 4 (4.3%) under drought condition with the application of 0.6% Silixol as compared to drought ones. These results are in accordance with the findings reported by Kobra Maghsoudi *et al.,* (2016) and Nishida and Murata (1996). This may be explained on the basis of fact that Silicon is capable to protect cell membrane under various abiotic stresses and play a significant role to induce tolerance against drought stress. Similar findings were also reported by Ahmed *et al.* (2011a, 2011b) who stated that Si could decrease membrane permeability of sorghum under water deficit induced by polyethylene glycerol.

Total dry matter (g/m^2) was reduced in all nine genotypes under drought condition. It was noted that 0.6% Silixol application increased Total dry matter (g/m^2) in all genotypes in both the conditions (irrigated and drought). Maximum percent increase in total dry matter (g/m^2) was recorded in genotypes, Sahabhagidhan (25.0%), JKRH 3333 (23.2%) and IIRRH 131(22.0%) under drought condition with the application of 0.6% Silixol over drought only. These results are in agreement with the findings reported by Jawahar and Vaiyapuri (2010) and Muriithi *et al.* (2010) who reported that Sulphur and Silicon may enhance total dry matter production and grain yield

of rice. They also observed that rice blast may be effectively managed by using Silicon sources.

The mean of Number of panicles per plant was reduced by >14% under drought treatment in comparison with irrigated control. The maximum percent increase in panicle number per plant was recorded in JKRH 3333 (40.0%), HRI 174 (33.3%), 27P63 (28.6%) under drought condition with the application of 0.6% Silixol in comparison with drought control.

In regard to Number of grain per panicle, it was recorded maximum grains number per panicle was recorded in genotypes, in US 314 (136.0), HRI 174 (132.0), 27P63 (130.7) and JKRH 3333 (130.7) under drought condition with the application of 0.6% Silixol (T3) in the comparison with drought only.

In regard to 1000 weight, it was significantly affected in the drought condition in comparison with the irrigated ones. However, imposing drought stress after flowering stage the mean percent reduction in 1000 grains weight was 16.8% in comparison with irrigated treatment. Application of Silixol on drought stressed crop resulted maximum 1000 grains weight in genotypes, US 314 (21.1 g), KRH 4(21.0 g), Sahabhagidhan (20.6 g) and IRRH 132 (20.1 g) in comparison with drought only

Application of Silixol resulted increase in grain yield in the both treatments irrigated as well as drought condition in comparison with their control ones. Maximum grain yield was recorded in genotypes, US 314 (101 q/ha), 27P63 (99 q/ha), HRI (99 q/ha) and KRH 4 (91 q/ha) under irrigated condition with 0.6% Silixol in comparison with their control ones whereas, maximum grain yield was recorded in these genotypes, US 314 (84 q/ha), 27P63 (82 q/ha), HRI (81 q/ha) and KRH 4 (71 q/ha) under drought condition with 0.6% Silixol in comparison with their control ones .

In regard to Harvest Index (HI) Silixol application significantly increased optimum in both the treatments irrigated as well as drought stress. Among the tested genotypes the mean of HI was recorded 47% in irrigated

condition and 43% was recorded under drought stress condition It was noted that maximum percent increase in HI was recorded in genotypes, Sahabhagidhan (7.1%), IIRRH 122 (6.1%) and KRH 4 (2.5%) under drought with the application of 0.6% Silixol in comparison with the drought ones .The results are in conformity with the findings reported by Rambo et al. (2011) Jawahar et al., (2015), Yoshida *et al.,* 1959; Okuda and Takahashi, (1961), Ma *et al.,* (1989) and Lee *et al., (*1990) who stated that Silicon application may enhance the yield attributing components very effectively in rice and other crops .

Chapter -VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

SUMMARY, CONCLUSION AND SUGGESTION FOR FURTHER WORK

The research on "Influence of Silicon on leaf blast of rice (*Pyricularia grisea*) and their relationship on morphophysiological and yield attributing traits under drought stress" were conducted at Department of Plant Pathology, JNKVV College of Agriculture, Rewa with the following objectives: -

Objectives

5. Evaluation of rice genotypes against leaf blast of rice.
6. Bioassay of Silixol against *Pyricularia grisea* and their effect on sporulation.
7. Assessment of morphophysiological parameters due to leaf blast under drought stress.
8. Influence of Silixol against leaf blast of rice and yield attributing traits of rice genotypes under drought stress.

6.1 Summary

The findings of the current research are summarized as under:

Pyricularia grisea shows maximum growth in Oat Meal Agar and Potato Dextrose Agar medium with traces of sporulation in comparison to other tested medium .

Pyricularia grisea shows maximum growth at 25°C temperature in Potato Dextrose Agar medium with traces of sporulation. As the temperature increase 35°C, it reduces the growth and sporulation.

Pyricularia grisea shows maximum growth in Potato Dextrose Agar medium with traces of sporulation in pH-6 and pH-5 in Potato Dextrose Agar amended medium. As the pH decreases the growth and sporulation reduce due to alkaline medium requirement for pathogenic fungi.

Nine genotypes of rice were evaluated against leaf blast of rice under natural conditions using 0-9 IRRI scale for the assessment of disease reaction .The data indicate that two genotypes namely US314 and 27P63 exhibited resistant reaction ranging from 3 to 4 disease score whereas, genotypes IIRRH122, IIRRH131and Sahabhagidhan showed moderately resistant reaction (4 to 6 score) and HRI 174, KRH4 JKRH3333 and IIRRH132 exhibited susceptible reaction under field study

Four different concentrations of Silixol@0.3%, 0.6%, 0.9% and 1.2% were evaluated against *Pyricularia grisea* in different period of incubation for the assessment of mycelial growth and Sporulation in Potato Dextrose agar medium and compared with standard fungicide Carbendazim 50WP@0.1% over untreated check. Among the treatment, Silixol@0.9% gave optimum mycelia growth(59.3mm) followed by Carbendazim (56.6mm) over Control (67.9mm).

Percent disease index (PDI) indicate that it may varied ranging from 42.25 to 41.77% in the genotypes evaluated in drought and irrigated ecology in different treatments. It is obvious from the data that maximum PDI 41.77% was recorded in HRI174 followed by JKRH3333 (38.44%) and KRH4 (27.65%) in irrigated conditions in untreated check

The susceptible cultivars HRI174. KRH4, IIRRH132 and JKRH3333 exhibited maximum plant height, number of tillers and minimum panicle length and yield. Whereas panicle length and yield were recorded maximum in resistant cultivars US314, 27P63, IIRRH121, IIRRH131 and Sahbhagidhan.

Seed germination is the most essential fundamental and vital phases in the growth cycle of plants that determine plant establishment and the yield of the crops. Germination were recorded in US-314(89%), Sahabhagidhan (89%), JKRH3333 (88%) and KRH-4(88%) under irrigated conditions whereas, under drought condition these genotypes showed 68%, 71%, 72% and 79% respectively.

In regard to Root length and shoot length, the tested genotypes, 27P63(15.0 cm), KRH-4(14 cm) US-314(14.0 cm) and IRRH-132(13.0 cm)

showed maximum root length, whereas, maximum shoot length was recorded in genotypes, IRRH132(18.0 cm), 27P63 (18.0 cm) and US-314(16.0 cm) under drought condition with the application of 0.6% Silixol over drought only.

It was found that application of 0.6% Silixol showed positive effects on greater leaf area index under both the conditions. The genotypes that had shown high leaf area index were IIRRH131 (7.79) followed by JKRHJ3333(7.60), IIRRH131(7.58) and US 314(7.33) under irrigated Silixol application whereas, minimum leaf area was recorded in KRH4(4.19), JKRH3333 (5.27) and IIRRH122(5.30) under drought condition.

In regard to tillers per plant, maximum number of tillers was recorded in 27P63 (13) followed by Sahabhagidhan (12), HRI 174(12) and US 314(11) under drought condition with the 0.6% Silixol application, whereas, under drought condition same genotypes gave 7, 9, 8 and 9 tillers per plant respectively.

Relative water content (RWC) of rice was also studied in the genotypes in drought and irrigated ecology with the application of Silixol. Among the tested genotypes, maximum percent increase in RWC in response to 0.6% Silixol was recorded in JKRH 3333(8.6%), IIRRH132 (5.9%) and IIRRH131(3.7%) under irrigated condition over without application of Silixol under irrigated condition.

Application of Silixol @0.6% increased significantly membrane stability index (MSI) of leaves of all the tested genotypes under drought condition. Maximum percent increase of MSI was exhibited in 27P63 (14.5%) followed by Sahbhagidhan (9.4%), IRRH 132 (8.3%) and KRH 4 (4.3%) under drought condition with the application of 0.6% Silixol as compared to drought ones.

Maximum percent increase in total dry matter (g/m^2) was recorded in genotypes, Sahabhagidhan (25.0%), JKRH 3333 (23.2%) and IIRRH 131 (22.0%) under drought condition with the application of 0.6% Silixol over drought only.

The mean of Number of panicles per plant was reduced by >14% under drought treatment in comparison with irrigated control. The maximum percent increase in panicle number per plant was recorded in JKRH 3333 (40.0%), HRI 174 (33.3%), 27P63 (28.6%) under drought condition with the application of 0.6% Silixol in comparison with drought control.

In regard to Number of grain per panicle, it was recorded maximum grains number per panicle was recorded in genotypes, in US 314 (136.0), HRI 174 (132.0), 27P63 (130.7) and JKRH 3333 (130.7) under drought condition with the application of 0.6% Silixol (T3) in the comparison with drought only.

Application of Silixol on drought stressed crop resulted maximum 1000 grains weight in genotypes, US 314 (21.1 g), KRH 4(21.0 g), Sahabhagidhan (20.6 g) and IRRH 132 (20.1 g) in comparison with drought only

Maximum grain yield was recorded in genotypes, US 314 (101 q/ha), 27P63 (99 q/ha), HRI (99 q/ha) and KRH 4 (91 q/ha) under irrigated condition with 0.6% Silixol in comparison with their control ones whereas, maximum grain yield was recorded in these genotypes, US 314 (84 q/ha), 27P63 (82 q/ha), HRI (81 q/ha) and KRH 4 (71 q/ha) under drought condition with 0.6% Silixol in comparison with their control ones .

In regard to Harvest Index (HI) Silixol application significantly increased optimum in both the treatments irrigated as well as drought stress. Among the tested genotypes the mean of HI was recorded 47% in irrigated condition and 43% was recorded under drought stress condition. It was noted that maximum percent increase in HI was recorded in genotypes, Sahabhagidhan (7.1%), IIRRH 122 (6.1%) and KRH 4 (2.5%) under drought with the application of 0.6% Silixol in comparison with the drought ones.

6.2 Conclusion

1. Among the tested rice cultivars US314, 27P63, IIRRH121, IIRRH131 and SAHABHAGIDHAN were found moderately resistant to leaf blast of rice under natural epiphytotics.

2. The significant variation in growth of *Pyricularia grisea* was recorded in different solid media namely Oat Meal Agar (OMA), Potato Dextrose Agar (PDA), Czapek Dox Agar (CDA), Richard Agar medium and Corn Meal Agar (CMA).However, OMA, PDA was found to be highly suitable for growth and sporulation of pathogen.

3. The growth and sporulation of *Pyricularia grisea* were studied on different Silixol concentration, pH and Temperature. It was noted that Silixol@0.6%, pH-6 and 25^0C temperature were found to be suitable for growth and sporulation of pathogen.

6.3 SUGGESTIONS FOR FURTHER WORK

With the increasing importance of leaf blast disease of rice intensive efforts and investigations will be needed to explore the possibilities to understand the factors contributing the perpetuation of the pathogen, mode of infection and spread under rain fed and irrigated ecosystem. The future strategies on this research work particularly lacking information's study will definitely help in the management of leaf blast. Following suggestions are given below:

1. Source of Silicon and their management practices should be developed and major stress will be given on integrated approaches.
2. Disease management through application of Silicon amended in fertilizers for effective adoption be studied.
3. There is need to find out or develop cheaper source of Silicon and standardising the most effective doses for mitigating drought stress and developing disease resistance in the crop.

Chapter - VII

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APPENDIX

APPENDIX

1. Analysis of variance for Influence of different culture media on mycelial growth and sporulation of *Pyricularia grisea.*

A. After 72 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F tab
Treatments	4	2419.56	954.89	17663.54	3.05
Error	15	0.453	0.049	-	-
Total	19	-	-	-	-

B. After 96 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F tab
Treatments	4	3122.09	1241.032	36243.97	3.05
Error	15	0.389	0.037	-	-
Total	19	-	-	-	-

C.After 120 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F tab
Treatments	4	4158.67	1407.17	62282.45	3.05
Error	15	0.301	0.029	-	-
Total	19	-	-	-	-

D.After 144 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F tab
Treatments	4	4388. 73	1457.68	53467.71	3.05
Error	15	0.242	0.020	-	-
Total	19	-	-	-	-

2. Analysis of variance for effect of Temperatures on mycelial growth (Diameter) of *Pyricularia grisea.*

A. After 72 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F tab
Treatments	3	532.12	174.37	4843.61	3.42
Error	9	0.324	0.036	-	-
Total	12	-	-	-	-

B. After 96 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F tab
Treatments	3	927.10	306.03	13305.6	3.42
Error	9	0.215	0.023	-	-
Total	12	-	-	-	-

C. After 120 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F tab
Treatments	3	2647.43	882.47	49026.1	3.42
Error	9	0.165	0.018	-	-
Total	12	-	-	-	-

D. After 144 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	F tab
Treatments	3	3794.47	1264.82	74401.1	3.42
Error	9	0.155	0.017	-	-
Total	12	-	-	-	-

3. Analysis of variance for effect of different pH on mycelial growth (Diameter) of *Pyricularia grisea.*

A. After 72 hrs

Source of Variation	DF	Sum of Squares	Mean Squares	F cal	F tab
Treatment	3	1,523.25	223.65	17,203.84	3.42
Error	9	0.123	0.013	-	-
Total	12	-	-	-	-

B. After 96 hrs

Source of Variation	DF	Sum of Squares	Mean Squares	F cal	F tab
Treatment	3	2,784.55	928.18	66298.57	3.42
Error	9	0.128	0.014	-	-
Total	12	-	-	-	-

C. After 120 hrs

Source of Variation	DF	Sum of Squares	Mean Sum of Squares	F cal	F tab
Treatment	3	5,432.80	1,810.66	452,665	3.42
Error	9	0.040	0.004	-	-
Total	12	-	-	-	-

D. After 144 hrs

Source of variation	DF	Sum of squares	Mean sum of squares	F cal	Ftab
Treatments	3	9648.24	3216.08	459440	3.42
Error	9	0.065	0.007	-	-
Total	12	-	-	-	-

4. Analysis of variance for effect of different concentration of Silixol on mycelial growth and sporulation (Diameter) of*Pyricularia grisea.*

A. After 72 hrs

Source of Variation	DF	Sum of Squares	Mean sum of squares	F cal	F tab
Treatment	5	495.87	217.33	16875.43	2.77
Error	18	0.051	0.012	-	-
Total	23	-	-	-	-

B. After 96 hrs

Source of Variation	DF	Sum of Squares	Mean sum of squares	F cal	F tab
Treatment	5	2143.41	321.31	18058.23	2.77
Error	18	0.191	0.018	-	-
Total	23	-	-	-	-

C. After 120 hrs

Source of Variation	DF	Sum of Squares	Mean sum of squares	F cal	F tab
Treatment	5	3473.37	532.73	28773.28	2.77
Error	18	0.164	0.016	-	-
Total	23	-	-	-	-

D. After 144 hrs

Source of Variation	DF	Sum of Squares	Mean sum of squares	F cal	F tab
Treatment	5	4149.2	1517.4	36313.50	2.77
Error	18	0.051	0.007	-	-
Total	23	-	-	-	-

5. Analysis of Different Silicon sources for the management practices of leaf blast of rice *Pyricularia grisea.*

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F tab
Replication	3	14.48	7.24	14.19	3.89
Treatment	4	422.26	70.37	137.99	3.00
Error	12	6.12	0.51	-	-
Total	17	422.86	-	-	

6. Analysis of variance of grain yield (q/ha)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	F tab
Replication	3	16.24	8.12	11.09	4.32
Treatment	4	452.02	75.33	132.01	4.00
Error	12	7.12	0.59	-	-
Total	17	352.20	-	-	

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For the partial of the master's degree programme he was allotted a field research experiment on, **"Influence of Silicon on leaf blast of rice (*Pyricularia grisea*) and their relationship on morphophysiological and yield attributing traits under drought stress"** which was successfully conducted by him and being submitted in the form of this thesis.