REACTION OF RICE GERMPLASM TO BLAST AND BROWNSPOT UNDER NATURAL AND CONTROLLED ENVIRONMENT IN MWEA, KIRINYAGA COUNTY, KENYA

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This thesis is my original work and has not been submitted for the award of a degree in any other university

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I dedicate it to all my sisters, brothers, and friends for the support they gave give all along.

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ABBREVEVIATIONS

AATF: African Agricultural Technology Foundation

AUDPC: Area Under Disease Progress Curve

BBSRC: Biotechnology and Biological Sciences Research Council

KAFACI: Korea- Africa Food and Agriculture Initiative

KALRO: Kenya Agricultural and Livestock Research Organization

IRRI: International Rice Research Institute

NERICA: New Rice for Africa

PDA: Potato Dextrose Agar

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ABSTRACT

Kenya has been losing tons of rice yield as a result of blast and brown spot of rice. The germplasm that farmers use is much susceptible to the two rice diseases. The rice breeders on the other hand are doing their best to come up with germplasm that can grow under normal field conditions and tolerate the attack of blast and brown spot to give a meaningful yield. After coming up with a number of blast and brown spot resistant germplasm farmers do not have information on which among them is most suitable. The objective of this project was to screen a huge number of germplasms produced by various breeders to identify which germplasm resisted blast and brown spot of rice under the local field conditions. As farmers are much interested in yields the performance of the rice germplasm would also be evaluated under field conditions.

Rice crop is affected by many foliar diseases, among them rice blast, brown spot of rice and bacterial blight of rice. The rice diseases affect the productivity of the farms and the resultant profits by farmers. Farmers are forced to buy chemicals in an attempt to manage the foliar diseases of rice. Such programs are governed by research institutions but the farmers are not informed on matters concerning disease resistance.

Sixty-four and 116 germplasm were planted in two separate experiments to screen for resistance against the rice foliar diseases. Each germplasm was planted in a plot 100cm by 30 cm and the whole experiment replicated three times. A path one meter wide was left between the blocks to allow accessibility to the plots. Agronomic activities like weeding and application of fertilizer were done and the disease scored on separate scoring sheet. Data was collected on number of tillers and height of the different germplasm. Diseased plant materials were collected and taken to the laboratory and the causal agent isolated to confirm the disease. It was also inoculated on the germplasms in a successive experiment and disease symptoms scored.

NERICA varieties displayed high tolerance to most of the rice foliar diseases. A few were susceptible to rice blast, brown spot of rice and bacterial blight of rice. Germplasm 1, 10, 12, 14, 17, 31, 41, 48, 64, 2, 19, 47, 51, 54, 56, 57 and 61 of the BBSRC germplsm in field experiment had a brown spot incidence of less than 1 percent hence tolerant to the disease. Eighty-two of the germplasm in KAFACI experiment one, field experiment had a brown spot incidence of less than two. Fifty three of the 116 KAFACI germplsm in the field experiment had a severity blast score below five hence tolerant to blast of rice. Rice lines 7, 11, 15, 17, 44, 47, 48, 49, 53 and 58 of the

BBSRC germplasm recorded no blast in the greenhouse experiment at any point of their growth hence considered resistant in experiment one.

Germplasm 39 and 56 of KAFACI experiment had the highest yield of 15 tons per hectare in each of the plot in the field experiment, while 31, 48, 30, 67, 27,4, and 50 also performed well with each plot yielding over 8 tons per hectare. The germplasm also had blast and brown spot tolerance and therefore most suitable for adoption in the local environmental condition. Among the BBSRC, germplasm 63 performed better than the rest with yield of over 18 tons per hectare, while germplasm 51 had over 16 tons per hectare in the field experiment. Germplasm 54, 29,39, 59,45 and 1 also performed well yielding over 13.5 tons per hectare. The germplasm grew vigorously, taller and tillering well which supported high yields.

It was found that 25 germplasm had resistance against blast and brown spot diseases of rice and can be utilized alongside other desirable production traits like high yielding to come up with superior rice seeds that can increase production of rice per unit land. Screening for resistance should continue to confirm the presence of resistance to foliar diseases of rice so that the genes can be introduced into the cultivars used by farmers. Rice breeders also need to generate local germplasm adopted to our environment and screen for several seasons for farmers to adopt.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Rice has been a significant crop to humanity for a very long time, dating to as early as 10,000 years ago (Arcieri and Ghinassi, 2020). Geological and archaeological evidence has proven that rice cultivation has been in existence for over 7000 years (Huan *et al.*, 2022). The domestication of rice has contributed significantly to man's civilization as he has been able to enhance productivity by selecting the crop with tolerance to diseases (Huan *et al.*, 2022). It once was a wild grass just like any other; later, it was refined to a plant that serves as a diet to most of the world population. Currently, it is a source of food to over half of the world's population (Fahad *et al.*, 2019). Apart from food, it has also served as a very crucial crop for genetic studies. The crop resembles other grasses in a variety of attributes. It grew in the wild as *Oryza rupifogon* but was domesticated by man to the current *Oryza sativa* over a long period by careful selection (Sangeetha *et al.*, 2020).

Rice production is an economic activity that happens in over 85 countries of the world. Some of them include China, India, Philippines, Pakistan, Bangladesh, and Indonesia. People consume approximately 491.5 metric tons of rice every year (Gadal *et al.*, 2019). Rice fields globally have an estimated production area of 163 million hectares. Efficiency of a single strategy used is also low and hence there is a need for them to be integrated and used in comparison to effectively manage the rice foliar diseases at a cheaper cost (Asibi *et al.*, 2019). One of the most embraced management strategies is the use of resistant cultivars. They can grow and get affected by the foliar disease but only display mild symptoms allowing farmers to get a meaningful harvest.

Cultivation of rice comes with many challenges, which make the process difficult and expensive. A significant problem that rice's farmers face and have to overcome is diseases in the rice field. Rice is attacked by very many diseases which have to be judiciously managed by the farmers. Rice production is affected by many foliar diseases that affect the crop. Important foliar diseases of rice include rice blast and brown spot of rice. The diseases reduce yields of rice and increases the costs of production in the attempt to manage them (Ahmed *et al.*, 2019). Rice farmers heavily depend on chemicals to control the foliar diseases of rice which apart from being expensive is not environment friendly.

1.2 Statement of the problem

Rice diseases have affected many farmers in the Mwea region (Samejima *et al.,* 2020). This has led to the county losing to as high as 50% of the cultivated crop (Devkota, 2020). A report by IRRI also indicates that the general consumption of rice in Kenya is growing at a rate of 12% per year. The trend in consumption is the same worldwide as it is expected that by the year 2030, 756 million metric tons will be consumed worldwide, a higher figure compared to 586 million metric tons consumed in 2001. Kenya consumes 538 ,000 metric tons but only produces 112,000 metric tons annually, making the country to depend on the imports heavily. Many factors contribute to the low rice productivity and among them is the presence of rice blast disease, brown spot, and bacterial leaf blight of rice (Fahad *et al.,* 2019). The diseases increase the average production cost as management measures require money. Currently farmers are having trouble in their attempt to manage the rice foliar diseases, they mostly depend on chemical fungicides which are expensive and detrimental to the environment. Losses caused by foliar diseases of rice can be reduced by planting cultivars that have disease tolerance. Few research has however been done to identify the germplasm with this desirable trait. Mutiga et el al in 2021 did a series of screenings and identified a significant number of rice lines with resistance to blast and brown spot diseases of rice. There is therefore a need for a continued series of similar experiment to confirm the presence and stability of this important trait. High yielding seed is planted but severe losses often occur when there is an outbreak of the rice foliar diseases (Godfray *et al.,* 2016).

1.3 Justification

Rice is an important global crop, providing food security to over half of the world's population. It is the most widely grown crop in the world, and one of the most important sources of food and nutrition for poor people in developing countries. The global production of rice is increasingly threatened by the spread of plant diseases, such as blast and brown spot of rice, which can devastate entire harvests. To combat this, there is a need for a global effort to screen and identify rice lines with resistance to these diseases. International Rice Research Institute has been carrying out extensive research tome up with rice that confer resistant to rice blast and brown spot diseases of rice. Individual national research institutes are also globally carrying out research activities to come out with rice germplasm with resistance to blast and brown spot of rice (Britwum et al., 2020). Similar research is carried out by IRRI and Kenya Agricultural and Livestock Research

Organization (Mutiga et al, 2021). It is crucial to identify existing resistant germplasm in the major production regions, as well as find new sources of resistance through breeding programs and genetic engineering. By doing this, we can reduce the risks of rice production and ensure food security for future generations. Rice production in Kenya can be improved by growing rice varieties tolerant of rice blast, and brown spot reducing production costs involved in spraying and yield losses caused by the two diseases (Nalley *et al.*, 2016). The tolerance is found in some varieties or can be incorporated through the various breeding processes or even genetic engineering (Tian *et al.*, 2016). Many organizations have come up to help farmers identify and grow the varieties that show tolerance to these diseases. After the various processes that are done to incorporate the resistance gene, it is always unclear which lines express the genes in the production environment. In this project, I collected 64 (BBSRC)and 116 (KAFACI) germplasm from the various organizations and tested for tolerance against rice blast and brown spot. The best varieties were recommended to farmers to adopt.

1.4 General objective

The broad objective was to contribute to the management of blast and brown spot of rice through host resistance

The specific objectives

i. To evaluate the reaction of selected rice germplasm to rice blast and brown spot
ii. To evaluate the agronomic and yield performance of selected rice germplasm

1.5 The hypotheses

i. The selected rice lines are susceptible to brown spot and blast diseases of rice as they lack genes that confer resistance to the foliar diseases
ii. The selected rice germplasm has better agronomic performance because they have undergone breeding

CHAPTER TWO: LITERATURE REVIEW

2.1 Rice production and importance in Kenya

Global rice production has increased significantly over the past few decades, with rising demand putting pressure on the agricultural sector to meet the needs of a growing population. In 2020, global rice production reached 494.9 million tonns, a 2.7 percent decrease from the previous year. The majority of the world's rice is produced in Asia, accounting for around 90% of global production, with India leading the way. China, Indonesia, Bangladesh, Vietnam, and Thailand all rank among the top ten rice producing countries in the world. The remaining 10% is largely split between Africa, South America, and North America, with the United States being the largest producer in the Americas. Rice production in Kenya began in 1907 after being introduced from Asia (Cheboi *et al.,* 2021). It is now the third most important cereal crop in the country after maize and wheat (Kihoro and Bosco, 2013). Most farmers grew rice for commercial purposes, but they have started to appreciate it as a food crop with time. Over 90% of rice produced in Kenya is done under paddy conditions, while 5% is rainfed. Kenya has got big potential for rice production but the sector has not received adequate support from policy and relevant institutions. Potential areas for rice production are the irrigated farm lands of Tana River Development Authority, Bura, and Hola irrigation schemes. Currently, Kenya produces approximately 112, 000 tons of rice (Kihoro and Bosco, 2013). This does not meet the countries annual consumption of approximately 538,000metric tons. The deficit is met by imports from Pakistan, Tanzania and India. The rate of rice production is however steadily increasing as a result of expansion of the irrigation schemes and the growing demand of rice locally which was not there previously.

2.2 The uses of rice

Rice provides carbohydrates to over half of the world’s population, especially those living in Asian countries. According to the World Health Organization in 2018, malnutrition can be reduced by fortifying rice with the micronutrients that are scarce in other diets and giving it to people who have little food. Such micro nutrients include Zinc, iron, Vitamin C and folic acid. Different varieties of rice have varying levels of nutritional composition (Vici *et al.,* 2021). Starch from rice manufactures ice cream, portable alcohol, and also pudding. Bran from rice manufactures bread, cookies, and biscuits (Rathna Priya et al., 2019). Husks that are produced are essential sources of fuel as they are burnt apart from preparation of compost manure compost can also be made from them. Farmers feed their animals on rice straw. Oils produced from bran make soap and fatty acid manufacturing. Most of the straw produced from rice is considered as waste and most farmers burn it (Hoang *et al.*, 2021). The straw can be used as mats in nurseries, it can also be utilized as growth medium and also laid in the field to control soil erosion. It has the potential to be used as biofuel (Van Hung *et al.,* 2019). In the manufacturing industry, rice straw can be used for paper making, the Japanese use rice to prepare alcoholic beverages.

2.3 Important foliar diseases of rice

There many general constraints facing rice production, rice is a highly land-intensive crop and with the limited availability of arable land coupled with rising population, the strain on land resources has increased significantly. This has led to land degradation, soil fertility decline, labor shortages, and lack of mechanization. The amount and quality of water available for rice production is decreasing due to climate change and increasing water demand from other sectors. Growing rice requires large amounts of water which limits the areas suitable for production. Rice is a delicate crop and problems with fertility, pest and disease issues as well as difficulties related to crop diversification and maintenance of yield levels has led to a decline in productivity. Rice production lacks modern technology which is vital for increasing yields and improving efficiency.

Rice is affected by many diseases like rice blast, bacterial leaf blight, and brown spot, (Jia *et al.*, 2019). Rice blast and brown spot of rice are crucial as they are much common and cause more significant yield losses, with rice blast alone causing 20 to 100% yield losses (Shahriar *et al.*, 2020). This is because rice blast reduces tillering and grain formation significantly. Rice disease varies in intensity across the different agro-ecological zones as a result of variation in the environmental factors like temperature, humidity and rainfall. Effects of the disease also vary across the season with one disease causing devastating effects on rice production in a particular period unlike the others. Bacterial disease like the bacterial leaf blight of rice is much severe and observed in nurseries when the crop is establishing. In the field fungal disease like rice blast and brown spot are the most common and causing huge losses.

2.4 Rice blast

2.4.1 Importance to rice crop

Rice blast results to over 30 percent crop losses globally and hence need to be managed well to ensure food security. Presence of rice blast in the field leads to increased global prices of rice and denies over 60 million people access to food (Nalley *et al.,* 2016). Over half of the world's population depends on rice as a stapple food. Management of rice blast through chemical, and breeding programs is costly and reduces the gross margin of farmers. Management of rice blast negatively impacts on the environment when chemicals are used, other organisms in the ecosystem that were not the target by the control strategy are killed yet they have a role they play disturbing the ecosystem. Rice is an important staple food in East Africa and Kenya particularly. It is a major source of calories and nutrition for the people in this region. Rice is abundant in East Kenya and is one of the main crops grown locally. It provides an important source of income and employment for the rural population and contributes significantly to local and national nutrition objectives. Rice is the staple food of many people in this region and is consumed in various forms such as boiling, steaming, mashing, and feeding. Eating rice is an important part of the culture and traditions in East Africa, and is a significant factor in helping people stay healthy. Rice also provides an important source of animal feed, making it an important part of the agricultural industry

2.4.2 Occurrence, distribution and host range

Rice blast has been reported in over 80 countries that grow rice, the foliar disease of rice affects both paddy rice and those grown in upland cultivation. Rice blast has been reported in all rice growing regions of the world across all the continents (Soubabere *et al.,* 2000). The occurrence of rice blast is affected by factors like rainfall, humidity and temperature which can be used in preparation of models to predict outbreaks. Plant growth stage also influence the likelihood of the disease affecting the crop. Rice blast epidemics have been reported in countries like Thailand and in California (Sutthiphai *et al.,* 2021). In an effort to curb the rice blast epidemic, the Thailand government has instituted several measures. In 2008, the government implemented an Integrated Disease Management System, consisting of pest resistance, trapping, field sanitation, and early detection. This system includes better agronomic practices, increased use of genetic and cultural resistance, and improved monitoring and detection of infections. The government also uses preventive treatments, including fungicide sprays and seed treatment.In Kenya rice blast diseases has been reported in all the rice growing regions which include Mwea and Embu regions, Kisumu region, Tana river and Mombasa Counties.

In addition, the government sponsors local and international research and extension efforts to better understand the disease, create improved seeds, and implement new technologies such as pesticide-infused traps. Efforts have also been made to strengthen extension services and post-harvest stewardship so farmers can better understand the fundamentals of disease management. *Magnaporthe oryzae* fungus is the causal agent of rice blast, it is indistinguishable from *Magnapothe grisea* which causes blast on crab grass. It causes symptoms on finger millet and other wild grasses like *Cynodon dactydon*. Reports of losses on wheat and barley farms due to neck blast are also present (Shanmugapackiam and Raguchander, 2018).

2.4.3 Symptoms

Rice blasts form diamond-shaped lesions which are elongated with a white center. Borders of the lesion become brown to reddish-brown (Li *et al.,* 2019). Collar rot is making the leaves fall off before maturity (Shahriar *et al.,* 2020). The panicles are not filled with grain turning white and then die. This symptom varies depending on the age of the plant, resistance of the plant to rice blast, and the environment (Shahriar *et al.,* 2020). Susceptible varieties show grey-green and water-soaked lesions on leaves with a dark green border (Shahriar *et al.,* 2020). The lesion expands faster to several centimeters. The lesions on susceptible varieties are light tan with boundaries that are necrotic. Lesions on resistant cultivars are dark brown in color and remain small 1-2 mm in length. As the lesions coalesce, the whole leaf eventually dies (Shahriar *et al.,* 2020).

When the collars are attacked, the whole leaf eventually dies and the lesion then extends into the sheath. This lesion produces some spores which can infect the pedicels, it then hinders seed formation. These fungi infect the seed after infecting the florets, seeds that are infected have brown spots (Agbowuro *et al.,* 2020). Infection of young seedlings leads to the death of the whole plant.

2.4.4 The characteristics of *Magnoporthe oryzae*

Rice blast is a fungal disease of rice that is caused by an ascomycete *Magnaporthe oryzae*. Rice blast fungi reproduce both sexually and asexually. The inoculum is usually present in the environment but may not cause epidemics as the environment might be unsuitable or the host is absent. Asexually, the fungi are described *as Pycularia oryzae*, most of the spore exists in this form (Prakash *et al.,* 2021). The fungi abundantly produce conidiophores, aerial mycelia are branched and olivaceous. Good conditions make the spores grow at the center of the lesions formed (Nizolli *et al.,* 2021).

This is very common in susceptible varieties and rare on resistant varieties. When the fungi are grown on agar, it grows gray and is fleecy. Conidia are produced after several hours of high humidity in the atmosphere (Nazifa *et al.,* 2021). The release of the spores is around midday (Shahriar *et al.,* 2020) and is very effective when there are strong winds to transport them. Blast disease epidemics are divided into the leaf blade, leaf collars, panicles, and nodes.

Various researchers have prepared and used multiple media to grow and multiply rice blast pathogens. Examples are rice bran agar, Potato Dextrose Agar, oatmeal agar, and rice leaf extract agar used by ((Song *et al.,* 2020), (Nazifa *et al.,* 2021), (Agbowuro *et al.,* 2020)). Mathurs prepared Mathurs media in 1960, but among all this, prune agar and oatmeal agar support maximum growth of the fungi. It takes an average of seven and a half days for the blast pathogen to sporulate on prune agar while it takes nine days to sporulate on oatmeal agar. On PDA, it takes pretty long, averaging at around 20 days, to sporulate. Upon sub culturing, sporulation happened between the 10 and 14 days.

2.4.5 Epidemiology of rice blast

Conidia are dispersed around by wind and water (Rodrigues *et al.,* 2020) and first deposited on the leaf surface of the rice plants. With favorable environmental conditions of temperature and humidity, the conidia germinate to form a germ tube and an appressorium. An infection peg develops on the appressorium followed by the ramification of the hyphae inside the host's tissue (Deng and Naqvi, 2019). There is also the sexual reproduction phase, where two opposite mate-type strains meet and then form a perithecium, the ascospores then develop inside. Some resistant varieties can restrict this hyphal growth. Spores are infective and the central propagation units that cause new rice blast infection (Quoc *et al.,* 2020). The disease is exhibited on different plant parts, including the leaves, collar panicles nodes, and the culm. The pathogen sporulates in the attacked plant tissue and then dispersed, one cycle takes a week when the environment is perfect.

Higher moisture and temperature raise the occurrence of the disease, it occurs at temperatures of 24 degrees Celsius (Asibi *et al.,* 2019). The disease will most likely occur when the humidity is high for over 12 hours. The initial source of inocula comes from host grasses in the wild, volunteer plants from the previous crops, debris, and infected seeds. Prolonged dew points favor rice blast (Asibi *et al.*, 2019). The lesions are observed 45-55 days after planting, the physical and micro climate plays a significant role in the sporulation of the pathogen (Mongiano *et al.*, 2021). Canopy wetness induces rice blast (Mongiano *et al.,* 2021). Mycelium on the straw can also serve as primary inocula (Huang *et al.*, 2019). Kodaty in 2020 demonstrated that rainfall correlated positively with rice blast (Kodaty and Halavath, 2020). Rice blast attacks the crop at its vegetative phase and finally affects the reproductive stage. This is when the spores produced at the end of the growing season strikes the collar. The spores then attack the neck when it emerges and has a severe effect on the yield compared to leaf blight (Shahriar *et al.*, 2020). Cycles of rice blast disease in the tropics are very high with one season producing ten cycles with three seasons a year. Disease epidemics are high during the extended periods of leaf wetness, higher humidity, and absents of winds (Agbowuro *et al.*, 2020).

2.5 Brown spot of rice

2.5.1 Importance of brown spot of rice

When heavily infected seeds are planted, brown spot occurs killing between 10 to 58 percent of the seedlings. Infection of rice by brown spot reduce number and quality of grains per panicle, the weight of the kernels produced is greatly reduced. Brown spot of rice can cause about 5 percent yield loss but when severe cases occur, it leads to over 45 percent yield loss. The foliar disease of rice has caused major epidemics in India like the Bengal famine which affected many people.

2.5.2 Occurrence, distribution and host range of brown spot of rice

The disease occurs in all areas that grow rice, including Japan, China, Russia, South America, Iran, Bangladesh, Sri Lanka, Africa, Malaysia, Philippines, and North America (Mohd Anuar *et al.*, 2020). Scarce water and nutrition imbalance like lack of nitrogen favors the disease. *Bipolaris oryzae* causing brown spot of rice have a wide host range. The pathogen has been tried on bermuda grass, downy brome, wild oat and yellow foxtail and observed to produce lessons.

2.5.3 Symptoms of brown spot

Seedlings with the disease have circular, yellow, or brown lesions and are observed after tillering. They develop fully and are surrounded by a reddish-brown margin resulting from the toxin they produce. The lesions are approximately 5-15 mm long, exhibiting slight differences between the susceptible and resistant cultivars. Parts of the plant infected include the glumes and panicle branches (Bharathkumar *et al.*, 2016), spots are brown, pinhead size, oval and dark brown in color. The sites have a typical yellow hallo (Archana and Sahayadhas, 2018). Lesions formed on the sheath resemble those found on the leaves. The disease has a negative impact on grain filling and the quality of the grains produced. The affected plants produce grains that are discolored and have some spots on their surfaces. The disease is found in the field all-round the season forming spots that coalesce hence drying up the whole leaf. A nursery with this disease appears scorched up while favorable conditions lead to the formation of conidiophores and conidia dark brown in color. The presence of this fungus in the seed hinders germination leading to pre-emergence damping off. Panicles show brown to the dark brown lesion, which extends downwards beneath the sheath. Severe rotting happens, and resultant grains are partially filled, chaffy and dull (Dariush *et al.*, 2021).

2.5.4: Losses due to brown spot of rice

Losses due to brown spot has been averaged at 5 % I n the Asian countries but can rise as high as 45% under severe attack. Planting the seeds with a higher inoculum level for this disease leads to seedling blight. This then translates to seedling mortality of approximately 10-58%. Grain yield losses vary with cultivar and the stage of development when the crop is attacked (Raju *et al.*, 2020). Sierra Leone has recorded 8.2 – 23% grain yield loss.

2.5.5 The causal agent of brown spot of rice

The disease is caused by *Cochliobolus miyabeanus* (Deng *et al.*, 2019) which lives in soils and survives in plant parts like stubbles, straw, and grains (Ogoshi, 2020). It can stay for 2-3 years and then serve as the primary inoculum to infect a clean crop. The fungi cause the failure of the seeds to germinate, root rot and make germinating seeds have less vigor. This pathogen produces inter and intra cellular mycelium. The mycelium appears as grayish brown to dark brown mat on the infected tissue. When this fungus is cultured, it appears as grey, olive to black in color. It has thick, erect, geniculate, dark olivaceous sporophores at the base and is lighter towards the tip. The sporophores penetrate through the stomata in groups of three to five. Septations on the conidia are about 5 to 10. The oldest conidia are found at the base and take a curved shape, with the middle being the widest. Mature conidia germinate with two polar germ tubes, each from the thin-walled regions. Those conidia that are not mature produce germ tubes from intermediary segments.

More sporulation occurs in the starch carboxy cellulose medium, peptone performs the best among the nitrogen sources. Corn meal agar, PDA and rice leaves agar supports maximum sporulation of *Cochliobolus miyabeanus* (Huang *et al.,* 2018). Chittaragi *et al.,* in 2018 showed much growth in malt extract and PDA after incubating for 96 hours. Temperatures were maintained at 28 degrees Celsius. When this pathogen is cultured, it produces phytotoxins. The cochliobolin inhibits root growth, coleoptiles, and even development of the leaves.

2.5.6 Epidemiology of brown spot of rice

Bipolaris oryzae can survive in the seed for over 4 years, it also survives in volunteer rice, weeds and infected rice debri. Brown spot of rice is common on nutrient deficient soils and those that have accumulated toxic compounds. Browns spot of rice is favored under temperatures of between 25˚C and 30˚ C. Infection happens under higher humidity of over 80 percent and continuous wetting of the foliage. When excessive nitrogen is applied to the soil, incidence of brown spot also increases.

Brown spot of rice affects many parts of the rice plant like the coleoptiles, leaves, leaf sheath, panicle branches, glumes, and spikelet. Its Occurrence is high in high humid areas, and suitable temperatures range between 16 and 36 degrees Celsius. Much of the infection happens when leaves are wet for 8-24 hours as the spores get enough time to germinate and infect the healthy tissue. The pathogen needs slightly lower temperatures while still at its developmental stage but as it reaches maturity, does well at elevated temperatures. Multiplication of the fungi happens well when rainfall has reduced, and there is plenty of due. Causal fungi can stay inside the seed for four years, and the central method by which the pathogen spread is through the air.

Some other factors like nutrition favor the development of brown spots in rice. Lack of essential minerals like potassium, nitrogen, manganese, phosphorus, and the mismanagement of micro nutrients favor the development of the disease. Sources of inoculum in the field include infected seeds (Pantha and Yadav, 2016), volunteer crops, and debris with the inoculum and weeds that act as alternative or alternate hosts. The disease is observed at all stages; the maximum effect is at tillering to the stage of ripening.

2.6 Approaches to management of diseases of rice

2.6.1 Management of rice blast

Management of rice blasts is complicated because this disease is widely distributed across all the regions that grow rice. The pathogen survives in so many alternative hosts. This makes control measures like crop rotation less effective. Spray of preventive and curative chemicals like Chariot 500SC 20ml/30L is widely practiced by rice farmers. The seeds are treated with carpropamid, probenazole tricyclazole that reduces blight development (Devkota, 2020). From the turn of the century to the second world war, Japan used copper fungicides to manage blast (Kumar and Ashraf, 2019). These fungicides had a higher level of plant phytotoxicity. Copper fungicides were then used but in combination with phenylmercuric acetate. It was more effective and caused less toxicity to plants. Different fungicides target different stages of the pathogen. Melanin biosynthesis inhibitors interfere with the normal formation of the appressorium. The choline biosynthesis inhibitors affect the membrane of the fungi. Ogawa discovered that when this was mixed with slaked lime, its efficacy increased (Srivastava *et al.,* 2017). They were then all banned because they all had higher mammalian toxicity and served as environmental pollutants. In the 1970s the organophosphorus fungicides were introduced. Fukunaga developed blasticidin S, which is a product of *Streptomyces griseochromogenes*. It acted well against blast after infection, but its action was less as a protectant. It showed low toxicity to both plants and animals ((Law *et al.,* 2017). The Discovery of Kasugamycin from *Streptomyces kasugaensis* exhibited less toxicity to mammals. Suryadi experimented on the possible efficacy of bacterial consortium to control blast on rice and found that some bacillus and pseudomonas bacteria inhibited the growth of *Pycularia oryzae* by 73 to 85 percent (Suryadibr *et al.,* 2013).

Nitrogenous fertilizer is applied in the split program to reduce nitrogen over-fertilization that encourages rice blast. Application of silica slag reduces blast incidence due to the formation of highly silicate cells of the epidermis. Rice grown in the tropics show minor blast disease when the crop is grown earlier in the season. The crop doesn’t get inoculum from the prior planted plants. Kenya Agricultural and Livestock Research Organization (KALRO) recommends farmers use tolerant varieties like IRRI2793-80-1, and Sindano (KALRO, 2016). Flowable formulations of *Bacillus subtilis* have been used to control rice blast (Chakraborty *et al.,* 2021). Resistance may not be that long-lasting as these fungi can quickly mutate and form resistant strains (Jia *et al.,* 2019).

Experiments on botanicals on the control of rice blast have proved effective. Leaf extracts from *Atlantia morphylla*, plumbago, and neem has exhibited blast suppression. Aqueous extracts of *Aloe vera, Allium sativa, Bidens pilosa* have been tried in Tanzania and found to affect the mycelial growth of the pathogen (Hubert *et al.,* 2015). There is also the development of blast tolerant rice that has been genetically modified. Some have a bacterial flagellin gene got from *Acidovorax avenea*. Another blast tolerant rice has been incorporated a harpin encoding gene found in *Xanthomonas oryzae* (Zou *et al.,* 2006). Presents of silicon compounds in the rice plant tissues enhance the plant resistance to blast as phenolic like compounds, diterpenoids, and Phyto alexins are formed.

2.6.2 Management of brown spot

Some of the essential fungicides for proper control of the disease are iprodione, propiconazole, and azoxystrobin. Maximum reduction in mycelia growth has been observed with Ridomil followed by Dithan M-45, CuOCl, Vitavax, Dazomil, Trimaltox. Those soils for growing rice that is deficient in silicon should be applied with calcium silicate. Farmers should ensure that they buy their seed from certified sources. Varieties grown in a particular area need to be screened to get and recommend those varieties that are found to be resistant to this particular disease. Management of the disease involves standard methods like planting varieties that are likely to resist brown spot of rice. It is also recommended that scouting be done in rice fields immediately after tillering to identify this disease. Urine from a cow at concentrations ranging from 30 to 70% reduces sclerotia formation.

Out of the 24 entries screened for resistance to brown spot of rice, the pigmented rice varieties displayed varying responses to resistance against brown spot (Mau *et al.,* 2020). One line was found to be resistant among the 29 entries screened (Mau *et al.,* 2020). Out of the 219 wild rice belonging to 15 Oryza species with all the six genomes for resistance originating from different places screened, 15 were resistant, and the other 78 to be moderately resistant. 165 japonica and indica lines were screened, and 54 had seedling resistance, 28 had adult resistance, while 22 had grain resistance. Some rice features associated with brown spot resistance are anatomical features like thicker epidermal cells and silicate cells (Zanão Júnior *et al.,* 2019). Rice is a silicon accumulator; the rice crop has a double layer of silica below the cuticle that restricts pathogen penetration. Another factor influencing resistance to brown spots is leaf angle, where brown spots increase with enlarged leaf angle. Infection is lower on narrow angled and the top most leaves. Mohd Anuar *et al.*, 2020, tried to control brown spot using seven isolates of Trichoderma by dual plate technique. He concluded that by the sixth day, maximum inhibition of up to 99% had been recorded. Citronella oil lemon grass oil, and Botos have been found to suppress brown spots in an ecological friendly way (Saroj *et al.*, 2018). Rhizobacteria, Agrobacterium, and Pseudomonas, have exhibited antagonism against *Bipolaris oryzae*. Zarandi *et al.*, in 2009 screened 20 actinomycete against brown spot pathogen and found five to have the highest activity. Harish in 2004 proved that the extract of turmeric inhibits the mycelial growth of *Bipolaris oryzae*. Other essential hosts for this disease are Oryza, *Leersia*, Zizania, Zea mays, and *Echinochloa colona*. Brown spot is an indicator of unfavorable environmental conditions (Songsomboon *et al.*, 2018). The crop may not be able to take in nitrogen from the soil due to water beetle destroying the roots of the crop.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Evaluation of the reaction of selected rice germplasm to rice blast and brown spot

3.1.1 Description of the study area

The experiment was carried at Kenya Agricultural and Livestock Research Organisation (KALRO) Mwea, an Industrial Crop Research Center. The site is in the Mwea East sub-county in Kirinyaga County. It is located 21 kilometers southwest of Embu town and 112 kilometers northeast of Nairobi. The elevation of the site is 1159 meters above sea level. It lies on latitude 00º 37ˈS and longitude 37º 20ˈE (Kagito and Gikonyoi, 2020). The area has black cracking clay soils, vertosols (Samejima *et al.*, 2020). The topography of the area is slightly irregular, with a slope of less than 1%. Average temperatures range between 23º C and 25º C (Samejima *et al.*, 2020).

3.1.2 Description of the experimental materials

Different rice lines from rice breeders were assessed for host resistance against rice blast and brown spot. Several lines were got from the Korea-Africa Food Agriculture Cooperation initiative (KAFACI), International Rice Research Institute (IRRI), NERICA lines, African Agriculture Technology Foundation (AATF). Each had a series of rice lines which were also screened alongside the locally grown rice lines. These lines have different levels of host resistance against the above two diseases. These varieties were evaluated on their response to rice blast and brown spot of rice. The following rice lines were obtained from the partner institutions for the screening experiment.

Table 3. 1: List of the Biotechnology and Biological Research Council rice lines tested in the field, experiment one

Serial no	Pedigree name	Genetic code	Generation description	Characteristics of the germplasm
1	IR130411(BASMATI217.2/WHO-1S-75-127	Bas 217.75-1-127	BC1F2	Resistant to blast
2	BASMATI370.2/WHO-1S-75-127	Bas 370.75-1-127	BC1F2	High yielding
3	BASMATI 217XC039-A15	Bas 217(pi2/9-A15)-Partial R	BC1F2	Resistant to brown spot
4	BASMATI370XWHO-IS-75-1-12	Bas 370pi 2/9-A15)-Partial R	BC1F2	Disease resistant
5	NERICA 12 XC039-A15	Nerica 12(pi 2/9-A15) Partial R	BC1F2	Early maturing
6	NERICA 12 X WHO-IS 75-1-127	Nerica 12 (Pi 9)	BC1F2	Resistant to brown spot
7	NERICA2 X C039-A15	NERICA 2 (Pi 2/9-A15)-Partial R	BC1F2	High yielding
8	NERICA 2X WHO IS-75-1-127	NERICA 2 (Pi 9)	BC1F2	Resistant to brown spot
9	BASMATI 217 X WHO-IS-75-1-127	BAS 217(Pi9)	BC1F2	High yielding
10	BASMATI370 X WHO-IS-75-1-127	BAS 217(Pi9)	BC1F2	Resistant to rice blast
11	NERICA 12X WHO-IS-75-1-127	Nerica 12 (Pi 9)	BC1F2	Early maturing
12	NERICA 2X WHO WHO-IS-75-1-127	Nerica 12(Pi9)	BC1F2	Resistant to blast
13	IR126183-1-1-1:CO39-A43(CO39.4/IR63372-8L8)	COS39(Pi2/9-A42)-Partial R	BC1F4	Resistant to brown spot
14	IR126184-1-1-1:CO39-A56(CO39.4/LUA MHEDEN: IREC16724-1	COS 39(Pi 2/9-A56)-Partil R	BC1F4	High yielding
15	IR126182-1-1-1:CO39-A35(CO39.4/CIRAD 394L(1)	11-3 COS 39(Pi 2/9-A35)-Partial R	BC1F4	Resistant to blast
16	IRBL-F5	3-11	Monogenic line	Resistant to blast

17	IRBL 5-M	20-11	Monogenic line	Resistant to blast
18	IRBL KS-S	5-11	Monogenic line	High yielding
19	IRBL1-CL	18-11	Monogenic line	Resistant to brown spot
20	IRBL3-CP 4		Monogenic line	Resistant to brown spot
21	IRBL SH-B	17-11	Monogenic line	Resistant to blast
22	IRBL KS-F5	4-11	Monogenic line	Resistant to brown spot
23	IRBL KH-K3	8-11	Monogenic line	High yielding
24	IRBL SH-S	16-11	Monogenic line	Resistant to brown spot
25	IRBLIRBL TA CP1	29-11	Monogenic line	Resistant to brown spot
26	IRBLK- KA	6-Nov	Monogenic line	Resistant to blast
27	IRBLK-KA	11-11	Monogenic line	Resistant to blast
28	IRBL ZT T	30-11	Monogenic line	High yielding
29	IRBL 11-ZH	21-11	Monogenic line	Resistant to blast
30	IRBL 7-M	2-11	Monogenic line	Resistant to brown spot
31	IRBL A-C	7-11	Monogenic line	Resistant to blast
32	IRBL KP-K60	11-31	Monogenic line	Resistant to blast
33	IRBLTA 2-RE	7-11	Monogenic line	Resistant to brown spot
34	IRTP 16211 (LTH)	11-32	Susceptible check background for monogenic lines	High yielding
35	IRTP1612 RE	7-11	Monogenic line	Resistant to blast
36	GYEHWA 3	NSFTV 62	African cultivar	Resistant to blast
37	WITA 3	AR-67	African cultivar	Resistant to blast
38	75-1-127	Pi 9donor	International cultivar	High yielding
39	TXD306	TZLR-74	African cultivar	Resistant to blast
40	WA96-1-1	AR -47	African cultivar	Resistant to brown spot

41	CHIEM CHIANH	NSFT V30	African cultivar	High yielding
42	EWINTO YIBO	EN-10	African cultivar	Resistant to blast
43	RT 0034	AR 34	African cultivar	High yielding
44	NSFTV284	AR-106	African cultivar	Resistant to blast
45	SHANGYU 394	NSFTV616	African cultivar	Resistant to blast
46	BINUWALAN	NSFTV 284	African cultivar	Resistant to brown spot
47	CHONDONGII	NSFTV232	African cultivar	Resistant to brown spot
48	KAMENOO	NSFTV 17	African cultivar	Resistant to blast
49	TOPLOEA 70/76	NSFTV 32	African cultivar	Resistant to blast
50	IRBLZ 55-CA	Nov-31	Monogenic line	
51	Local	NSFTV 291	African cultivar	Resistant to brown spot
52	Local	Basmati 217	Poular African commercially cultivated	High yielding
53	Local	Basmati 370	Popular African commercially cultivated	Resistant to brown spot
54	Local	Nerica 12	African cultivar	Resistant to blast
55	Local	Nerica 2	African cultivar	Resistant to brown spot
56	Local	Komboka	Susceptible African cultivar	Resistant to brown spot
57	Local	Nerica 1	African cultivar	Resistant to blast
58	Local	Nerica 4	African cultivar	Resistant to brown spot
59	Local	Basmati 370	African cultivar	High yielding
60	Local	Basmati 217	African cultivar	Resistant to brown spot
61	Local	Nerica 1	African cultivar	Resistant to blast
62	Local	Nerica 4	African cultivar	Resistant to blast
63	Local	10	African cultivar	High yielding
64	Local	11	African cultivar	Resistant to brown spot

Table 3. 2: List of Korea Agriculture and Food Initiative germplasm tested in the field experiment two

Plot no	Genetic code	Characteristics	Plot no	Genetic code	Characteristics
1	SR33705F2-64-3-3-HV-1	Resistant to blast	21	PBR1000922-3	Early maturing
2	SR33705F2-76-1-1-HV-1	High yielding	22	SR34592-HB-1-HV-1	Resistant to brown spot
3	SR34605-HB3446-3-1	Resistant to brown spot	23	SR34598-HB-7-HV-1	Resistant to blast
4	SR34609-HB3483-78-1	Resistant to blast	24	SR34598-HB-8-HV-1	High yielding
5	SR23364-133-17-1-HV-1-2	Resistant to brown spot	25	SR34054-1-12-4-2-1-1	Resistant to brown spot
6	SR23364-133-261-1-HV-1-1	High yielding	26	SR34054-1-12-4-3-2-2	High yielding
7	SR23364-133-171-1-HV-1-1	Resistant to brown spot	27	SR34054-1-21-4-1-2-3	Resistant to blast
8	SR23364-133-184-1-HV-1-1	Resistant to blast	28	SR34054-1-21-4-1-3-3	Resistant to brown spot
9	SR23364-128-1835-1-HV-1-1	High yielding	29	SR34054-1-21-4-3-1-1	High yielding
10	SR23364-128-1907-1-HV-1-1	Early maturing	30	SR34054-1-21-4-3-1-3	High yielding
11	SR23364-128-1758-1-HV-1-1	Resistant to blast	31	SR34796-1-4-6-3-2-1	Resistant to blast
12	SR23364-128-1762-1-HV-1-1	Resistant to brown spot	32	SR34796-1-15-7-5-4-1	Resistant to brown spot
13	SR23364-128-1971-1-HV-1-1	High yielding	33	SR34034F3-71-2-1-1-3	Resistant to blast
14	SR23364-128-1982-1-HV-1-1	Resistant to blast	34	SR34042F3-22-1-1-1-2	High yielding
15	SR33705F2-60-1-1-HV-1-1	Resistant to blast	35	SR34042F3-22-1-1-1-3	Resistant to blast
16	SR33705F2-60-2-2-HV-1-1	Resistant to brown spot	36	SR34042F3-22-1-1-5-2	Resistant to brown spot
17	SR33705F2-61-1-3-HV-1-1	High yielding	37	SR34042F3-22-1-1-5-3	High yielding
18	SR33705F2-61-3-2-HV-1-1	High yielding	38	SR35300-1-HV-1-2	Resistant to blast
19	SR33705F2-67-1-1-HV-1-1	Resistant to blast	39	SR33705F2-60-1-2-HV-1-2	Resistant to brown spot

20	PBR1000653-2	Resistant to brown spot	40	SR34053(#5-52)-1-4-2-10-1-2	Resistant to blast

41	SR34053(#5-52)-1-4-2-10-3-1	High yielding	61	SR35278-2-10-1-3	Resistant to brown spot
42	SR34053(#5-52)-1-4-2-10-3-2	Resistant to brown spot	62	SR35250-1-15-1-1	Resistant to blast
43	SR34053(#5-52)-1-4-2-10-3-3	Resistant to blast	63	SR35250-1-23-2-1	Resistant to brown spot
44	SR35285-2-8-4-1	High yielding	64	SR35250-1-23-2-3	High yielding
45	SR35274-5-1-1-2	Resistant to brown spot	65	SR35250-2-3-1-1	Resistant to brown spot
46	SR35274-5-1-2-1	Resistant to blast	66	SR35250-2-4-2-3	Resistant to blast
47	SR35276-2-4-3-1	Resistant to brown spot	67	SR35250-2-6-2-1	High yielding
48	SR35276-2-4-3-2	Resistant to blast	68	SR35250-2-15-2-2	Resistant to blast
49	SR35276-2-4-3-3	Resistant to blast	69	SR35250-2-19-1-2	Resistant to brown spot
50	SR35278-1-7-2-2	High yielding	70	SR35250-2-19-1-3	Resistant to brown spot
51	SR35278-1-7-3-2	Early maturing	71	SR35250-2-19-3-1	Resistant to brown spot
52	SR35278-1-9-2-1	Resistant to blast	72	SR35250-2-19-3-2	Resistant to blast
53	SR35278-1-9-2-2	Resistant to brown spot	73	SR35266-2-4-1-1	High yielding
54	SR35278-1-9-1-2	High yielding	74	SR35266-2-4-4-1	Resistant to blast
55	SR35278-1-9-1-3	Resistant to brown spot	75	SR35266-2-5-2-1	Resistant to brown spot
56	SR35278-1-9-3-1	Early maturing	76	SR35266-2-6-1-1	High yielding
57	SR35278-1-9-3-3	Resistant to blast	77	SR35266-2-6-2-1	Resistant to brown spot
58	SR35278-2-8-2-1	Resistant to brown spot	78	SR35266-2-7-1-1	Resistant to blast
59	SR35278-2-8-2-3	High yielding	79	SR35266-2-6-2-1	Resistant to blast
60	SR35278-2-10-1-2	Resistant to blast	80	SR35266-2-7-3-1	High yielding

81	SR35266-2-8-4-1	Resistant to brown spot	99	SR35266-3-1-3-1	Resistant to blast
82	SR35266-2-11-1-1	Resistant to blast	100	SR35266-3-1-5-1	Early maturing
83	SR35266-2-11-4-1	High yielding	102	SR35266-3-2-4-1	Early maturing
84	SR35266-2-12-1-1	Resistant to brown spot	103	SR35266-3-3-1-1	Early maturing
85	SR35266-2-12-2-1	High yielding	104	SR35266-3-3-5-1	Resistant to blast
86	SR35266-2-12-4-1	Resistant to blast	105	SR34590-HB3433-1-1-1	Resistant to brown spot
87	SR35266-2-12-5-1	Early maturing	106	SR34590-HB3433-1-3-1	High yielding
88	SR35266-2-16-1-1	High yielding	107	SR34590-HB3433-2-1-1	Resistant to blast
89	SR35266-2-16-2-1	Resistant to brown spot	108	SR34590-HB3433-2-2-1	Resistant to brown spot
90	SR35266-2-16-3-1	Resistant to blast	109	SR34590-HB3433-3-1-1	High yielding
91	SR35266-2-17-1-1	Early maturing	110	SR34590-HB3433-4-1-1	Resistant to blast
92	SR35266-2-17-2-1	High yielding	111	SR34590-HB3433-5-1-1	High yielding
93	SR35266-2-18-1-1	Early maturing	112	SR34590-HB3433-6-1-1	Resistant to blast
94	SR35266-2-18-2-1	Resistant to brown spot	113	SR34590-HB3433-6-2-1	High yielding
95	SR35266-2-18-3-1	Resistant to blast	114	SR34590-HB3433-7-1-1	Resistant to brown spot
96	SR35266-2-19-1-1	Early maturing	115	SR34590-HB3433-7-2-1	High yielding
97	SR35266-2-20-1-1	High yielding	116	SR34590-HB3433-7-3-1	Resistant to blast
98	SR35266-2-20-3-1	Resistant to brown spot			

3.1.3 Experimental design and layout

The experiment was carried out in Mwea experimental station located in Kirinyaga county between July 2021 and October 2022. Both season one and two of the experiments were grown in the main rice growing period of the year when all the other farmers were planting. The crop was irrigated using water from the main canals controlled by the National Irrigation Board of Kenya. Sixty-four rice lines were planted for experiment one (BBSRC) and 116 planted for experiment two (KAFACI Experiment) in the first seasons. During the second growing season, 40 germplasm were planted for experiment one and 100 germplasm planted for experiment two. The rice lines were from IRRI, KAFACI and NERICA rice lines.

Spreader rows were one meter wide, the path between adjacent blocks was one meter wide to facilitate convenient navigation while doing cultural activities or collecting data. The width of an individual block was 2.5 meters wide. Rice lines to be tested were planted in hills 20cm from each other on a straight line across the block. Lines were spaced 20 cm from each other, with each varietal line occupying three lines in a block. Each rice line from an individual breeder formed a separate experiment. Each experiment was replicated three times before moving to the next experiment. This was arranged in an alpha lattice design. Data was collected on disease incidence, severity and number of tillers for each of the germplasm. Yield was taken at the end of the growing season. Experiment one was planted in the field and had both the Biotechnology and Biological Research Council rice lines and the Korea Agriculture and Food Initiative rice lines while experiment two was planted in the screen house later in the season with 40 rice lines from Biotechnology and Biological Research Council and 100 rice lines from Korea Agriculture and Food Initiative rice lines

3.1.4 Establishment of rice crop

The land was prepared by ploughing and harrowing, the soil was well mixed and made even. The tractors were used in the process, the ground was the levelled. This was important because it ensured that less water was wasted by the uneven pockets of too deep water and exposed soil. This also ensured that seedlings were established much quickly. The crop was established by direct seeding, the seeds were placed in well-labeled khaki bags. The field to be transplanted was paddled with a tractor by mixing water with the soil to form a homogeneous soft soil. The field was left overnight to lose the excess water leaving behind wet soil not saturated with water. The field was marked, and the layout prepared using a rope. The blocks were marked, followed by the small plots in the three replications. Planting of the different germplasms was done in their respective plots and covered with a small amount of soil; seedlings emerged after three days.

Flooded conditions were maintained throughout the growing season. Low water levels were applied as the seedlings were tiny and gradually raised as the crop grew in height. Care was taken to ensure that the leaves were not submerged in water. The rice crop was planted with Sulphate of ammonia and later, after one month top-dressed with urea. The main destructive pest encountered included caterpillars, grass hoppers, and whiteflies. They were controlled by spraying with duduthrin, and their devastative effects were therefore managed.

The management of weeds was done using hand by manual labor. This was very effective but very expensive because one person could only handle a tiny portion per day. The weeds surrounding the experimental site, which included mainly grasses, were mainly controlled by spraying with round up. The crop in the field was irrigated by water from canals by opening the main gate valves to the field as the water attained the desirable levels. The gate valves were closed so that water passed to the other nearby fields. During periods of water scarcity, the rice crop was sustained by water from a small dam that was constructed in the research station that was a filled with water when it was plenty and applied to the fields using diesel pumps when there was no water. A large-scale screen for rice blast resistance was conducted on a large-scale on 180 germplasm. Natural infection was involved in the field; subsequent infection with blast isolate was also done in a screen house.

3.1.5 Preparation of plants for a screening experiment

For experiment one, 40 germplasm were planted in buckets; black cotton soil was mixed with cow manure in the ratio of 3:1 and mixed thoroughly. The soil was put in buckets until three-quarters full. Water was added to make the ground uniformly wet but not flooded. The soil was left overnight. Seeds were sown the following day. Forty germplasm was sown replicated three times. In another experiment, 100 germplasms were also planted and replicated three times. Three seeds were sown in each bucket. Moist conditions were maintained for a period of one week, but flooding was avoided. Seedlings emerged from the soil after three days. Any weeds that emerged were removed by hand; flooding of the crop begun the second week. Inoculation was done after 21 days.

Disease scoring was done one week after inoculation, where the size, shape, and color of the lesions were observed. The same was done for the KAFACI experiment, but in this experiment, plastic bags were used. A shade net covered the experiment to reduce the effect of direct sunlight on the inoculum. This also raised the humidity of the internal environment. The floor of the shade net was kept moist by sprinkling water every day to raise humidity. Disease evaluation was performed on each test line and scored on the standard IRRI scale 0 to 9, 0-4 representing resistant lines while 5 to 9 representing susceptible rice lines.

3.1.6 Assessment of disease incidence of blast and brown spot diseases of rice.

The incidence of the disease was collected by counting the number of rice plants in each plot that indicated symptoms of rice blast and divided by the total number of plants per plot and multiplying by one hundred.

Disease incidence for blast $= \frac{Number\ of\ plants\ showing\ blast\ symptoms}{Total\ number\ of\ plants\ per\ plot} \times 100$

Disease incidence for brown spot$=\frac{Plants\ showing\ symptoms\ for\ brownspot}{Total\ number\ of\ plants\ per\ plot} \times 100$

3.1.7 Assessment of the severity of rice blast and brown spot diseases of rice

Data about the disease severity were collected from the 21st day after emergence. Fifteen tillers were randomly selected in each rice line planted, and the diseased area was determined (Raveloson *et al.*, 2017). Disease severity was determined by a scale developed by IRRI in 1996. The size of the lesion, color, and area of the leaf-covered was determined. Assessment begun at the tillering state and end during the booting stage. Three severity data sets were collected during this period. The plants to be scored were randomly selected among all the rice plants in a plot. The leaves were observed for blast, brown spot and bacterial blight lesions.

Table 3. 3: The scoring scale of rice blast severity

Scale	Description	Host behavior
0	No lesion observed	Highly resistant
1	Small brown specs of pi8n point size	Resistant
2	Small roundish to slightly elongated, necrotic gray spots. About 1-2 mm in diameter with a distinct brown margin, lesions are mostly found on the lower leaves	Moderately resistant
3	Lesion type same as in two, but significant number of lesions on the upper leaves	Moderately resistant
4	Typically, susceptible blast lesions, 3 mm or longer infecting less than 4 percent of the area.	Moderately resistant
5	Typical susceptible blast lesions of 3mm or longer infecting 4-10 % of the leaf area.	Moderately resistant
6	Typical susceptible blast of 3mmor longer infecting 11-25 percent of the leaf area.	Susceptible
7	Typical susceptible blast lesions of 3 mm or longer infecting 26-50% o9fr the leaf area.	Susceptible
8	Typical blast lesions of more than 3mm or longer infecting 51-75 % of the leaf area many leaves are dead.	Highly susceptible
9	Typical susceptible blast lesions of 3 mm or longer infecting more than 75% leaf area affected.	Highly susceptible

Source: IRRI, 2021

Table 3. 4: Rating scale for brown spot of rice

Scale	Disease severity	Host response
1	Spots are not present, Small brown specs of pin point size on lower leaves	Highly resistant
2	Small roundish necrotic brown spot, about 1-2 mm in diameter with distinct brown margin.	Resistant
3	Spot size same as in 2 but significant number of spots on the upper leaves	Moderately resistant
4	Typical susceptible brown spot, 3mm or larger infecting less than 4% of the leaf area.	Moderately susceptible
5	Typical susceptible brown spot, 3mmor larger infecting 4-10% of the leaf area.	Moderately susceptible
6	Typical susceptible browns pot 3mm or larger infecting 11-25 percent of the leaf area.	Susceptible
7	Typical susceptible brown spot 3mm or larger infecting 26-50% of the leaf area.	Susceptible
8	Typical susceptible brown spot, 3 mm or larger infecting 51-75% of the leaf area.	Highly susceptible
9	Typical susceptible brown spot, 3mm or larger infecting more than 75% of the leaf area.	Highly susceptible

Source: Subedi *et al.*, 2016

3.1.8 Preparation of rice bran agar and rice straw extract agar

For rice bran agar, fifteen grams of bran was boiled in 500 milliliters of de ionized distilled water for one hour, 15 grams of agar was dissolved by heating in 500 milliliters distilled de ionized water. Fifty grams of bran was then mashed thoroughly and strained into the agar. The volume was adjusted to 1000 milliliters by adding distilled de ionized water (Nguyen *et al.*, 2016). Lactose and 4 grams yeast extract were added and stirred well, and then pH was adjusted to 6.5. Before the media cooled, it was dispensed into a media bottle. The media bottle was plugged with cotton and autoclaved for 15 min at 15 psi. Before plating the bran, agar, streptomycin was added after preparing by dissolving 0.2 grams into 100 milliliters distilled water. This formed 1000 parts per million stock solution; to prepare 50 parts per million, it had to be diluted 40 times. For the media to be 50 ppm, 1 milliliter of the stock solution was added to 25 milliliters of the media prepared.

In preparation of rice straw extract agar, rice leaves were chopped into 1 cm sections. One hundred grams of the chopped leaves were boiled in 1000 milliliter distilled for 30 minutes. The sections were strained out, 20 grams of agar was added. The media was autoclaved at 15 lbs and poured on plates, and left to cool (Nguyen *et al.*, 2016).

3.1.9 Isolation of *Magnaporthe oryzae*

Diseased plant material was got fresh from a crop showing symptoms and cut into small units 1cm wide and then surface sterilized in 1.5 sodium hypo chloride. The disinfected tissues were rinsed three times in distilled sterilized water. They were then placed on moistened filter paper to remove the excess water. The material was plated on PDA and then sub-cultured to get a clean pathogen (Al Noman and Shamsi, 2021). Incubation was done for three days at 26 degrees Celsius for 30 hours, making the pathogen sporulate (Widiantini *et al.,* 2017). Duration for incubation was then extended for another 12 days for characterization to be done. Data collected included the color and the shape of the margin. Any kind of sporulation was also recorded. Spores produced were stained using lactophenol blue and observed under a light microscope for the presence and number of septations (Al Noman and Shamsi, 2021). The pathogen was also grown on rice bran media and rice straw media.

3.1.10 *Magnaporthe oryzae and cochliobollus miyabeanus* inoculation preparation and inoculation of rice plants

Distilled water was poured on cultures of the fungal pathogen of *Magnaporthe oryzae*, a sterile slide gently scrapped it to dislodge the spores. The spore suspension was collected into one measuring cylinder. The stock solution was put on a hemocytometer to determine its concentration. The dimension of the hemocytometer was 0.1 millimeters; average conidia for *Magnaporthe oryzae* spores was 3 per square. The volume of the square is $0.1\times 0.1\times 0.1=0.001\ mm^3$, three conidia are found in $0.001\ mm^3$ of solution. Therefore, one milliliter contains 3000 conidia, 500 mm of conidia was prepared (Agbowuro *et al.,* 2020). It was also done to the *Cochlobollus miyabeanus* cultures to prepare conidial suspension.

Inoculation was done on 140 pots; 10 milliliters of the inoculum was applied to each pot. A total of 1400 millimeters was prepared. Pure distilled water was added to the plates that *Magnaporthe oryzae* was growing. It was scrapped gently with a clean slide to dislodge the conidia to be suspended in water. All the water conidial suspension from the different plates was collected in one glass jar. The suspension was filtered with a muslin cloth to remove mycelia and conidial suspension. Three drops of tween 20 were added, a few drops were placed on a microscope slide and observed for presence. Quantification was then done using a hemocytometer. One drop was placed on a hemocytometer, and a coverslip was put to expel some contents. The number of spores in a one-millimeter square was counted. Volume in one square is approximately 10^{-4} millimeters; hence the average number of spores per millimeter equals the average count per square × dilution factor. The conidial suspension was diluted to 10^{-5} and then quantified on a hemocytometer. The inoculum was placed in a clean, sterile spray bottle and applied to the host rice crop the same day. The application was made until run off; Spraying was done late in the evening to allow conidia to germinate overnight to infect the leaves. A shade was constructed over the crop. Observations were done every day for one week to observe for any infections. The appearance of lesions was scored according to IRRI scale 2012. The moisture maintained high above 95%. The same was repeated for brown spot pathogen (Priyadarshani *et al.*, 2018).

3.2 Evaluation of the performance of selected rice germplasm under the local environmental condition

3.2.1 Assessment of the agronomic parameters of rice

Performance of the selected rice germplasm were done by collecting data on tillering, height and yield of all the germplasm at a weekly interval (Stavrakoudis *et al.*, 2019). Data on yield and moisture content were collected at the end of the season during harvesting. A one-meter ruler was used to take data on plant height, the number of tillers were counted on samples collected randomly on the different line plots. Five plants were randomly sampled in each plot and tagged so that consistent data was collected. From the same plants, height and tillers were collected. Data was collected three times from tillering stage to booting stage. Tillers were physically counted on the sampled plant.

CHAPTER FOUR: RESULTS

4.1 Evaluation of the reaction of selected rice germplasm to rice blast and brown spot

4.1.1 Incidence and severity of blast for 64 and 116 rice lines under field and screenhouse conditions

Percentage blast incidence varied significantly among the 64 rice lines, ten rice lines did not record any blast incidence, while 11 of them were over 5 percent. The ten were among the rice lines with blast resistance as they were bred with anthocyanins that confer resistance to blast. Blast incidence was generally low in the field. Ten germplasms scored between 4 and 5 percent. Sixteen of the germplasm had an incidence of between one and two. The severity of rice blast significantly differed ($p<0.05$) among the 64 rice germplasms (Table 4.1). More than 90% of the germplasms had a severity score of less than two on the rice blast severity scoring scale. Only six rice germplasms (5,22,35,38,62,52) had a severity score that was greater than 2. Among the 64 rice germplasms, rice line 24 had significantly higher severity scores of rice blast than the rest of the germplasms.

In the 116 germplasm, a few rice lines had higher susceptibility, recording up to 14 percent (Table 4.2). Nine of the germplasm had a percentage blast incidence of over 10. Germplasm 88 had no blast incidence. The incidence did not vary significantly among the 116 germplasm. Fifty-three rice lines had a percentage rice line of below 5 percent. The resistance among the rice lines was high. There were no many significant differences in the blast severity of experiment two. All the germplasm recorded at least blast severity. 20 germplasm had a severity of over 1which revealed the presence of resistance in the 116 germplasms.

Table 4. 1: Incidence and the severity of blast for 64 Biotechnology and Biological Research Council rice lines in the field conditions.

Germplasm	Blast incidence	blast severity	Germplasm	Blast incidence	Blast severity	Germplasm	Blast incidence	Blast severity
1	1.9 ab	1.4 ab	23	1.0 ab	1.1 ab	45	4.1 ab	1.3 ab
2	4.4 ab	1.8 ab	24	5.7 ab	2.0 ab	46	1.0ab	1.1 ab
3	4.1 ab	1.4 ab	25	6.0 ab	1.8 ab	47	0.0 a	0.0 ab
4	4.8ab	1.3 ab	26	5.7 ab	1.8 ab	48	0.0 a	0.0ab
5	8.6 b	3.0 b	27	0.6 ab	1.3 ab	49	0.0 a	0.0 a
6	5.7 ab	1.7 ab	28	1.9 ab	1.1 ab	50	1.3 ab	1.1 ab
7	0 .0a	0.0 ab	29	4.1 ab	1.4 ab	51	0.6 ab	0.9 ab
8	5.1 ab	1.8 ab	30	1.9 ab	1.1 ab	52	7.3 ab	2.3 ab
9	2.2 ab	1.8 ab	31	0.6 ab	1.1 ab	53	0.0 a	0.0 ab
10	2.5 ab	1.3 ab	32	1.3 ab	1.1 ab	54	1.2 ab	0.9 ab
11	0.0a	0.0 ab	33	4.4 ab	1.8 ab	55	1.6 ab	1.3 ab
12	4.8 ab	1.4 ab	34	3.2 ab	1.2 ab	56	1.6 ab	1.6 ab
13	3.2 ab	1.7 ab	35	6.3 ab	2.1 ab	57	1.9 ab	1.6 ab
14	2.5 ab	1.3 ab	36	3.5 ab	1.8 ab	58	0.0 a	0.0 ab
15	0.0 a	0.0 ab	37	1.9 ab	1.6 ab	59	4.1 ab	1.7 ab
16	2.2ab	1.3 ab	38	2.2 ab	2.1 ab	60	0.6 ab	0.9 ab
17	0 .0a	0.0 ab	39	1.3 ab	0.9 ab	61	0.6 ab	0.9 ab
18	1.6 ab	1.3 ab	40	3.5 ab	1.7 ab	62	5.7 ab	2.2 ab
19	5.1 ab	1.8 ab	41	1.3 ab	1.0 ab	63	1.3 ab	0.9 ab
20	4.4 ab	2.0 ab	42	0.6 ab	1.1 ab	64	5.1 ab	1.6 ab
21	3.2ab	1.1 ab	43	0.6 ab	0.9 ab			
22	4.8 ab	2.2 ab	44	0.0 a	0 .0ab			
LSD	1.128	4.054						
C.V(%)	89.4	167.9						

Values with the same letter are not significantly different

Table 4. 2: Incidence and severity of blast for the 116 Korea-Africa Food and Agriculture Cooperation Initiative rice lines in the field conditions

Germplasm	Blast incidence	Blast severity	Germplasm	Blast incidence	Blast severity	Germplasm	Blast incidence	Blast severity
1	3.8 a	1.6 a	40	7.3 a	1. 0a	79	7.6 a	0.8 a
2	4.4 a	0.7a	41	2.5 a	0.7 a	80	3.2 a	0.2 a
3	4.8 a	0.9a	42	3.8 a	0.9 a	81	4.4 a	0.7 a
4	7.3 a	0.8a	43	4.4 a	1.0a	82	3.8 a	0.8 a
5	6.3 a	0.9a	44	8.3 a	0.8 a	83	7.0a	0.9 a
6	5.7 a	1.3a	45	3.8 a	0.7 a	84	7.6 a	0.8 a
7	6.7 a	0.8a	46	3.5 a	0.7 a	85	11.7 a	0.8 a
8	10.5 a	1.1a	47	5.1 a	0.9 a	86	5.7 a	0.8 a
9	11.7 a	0.7a	48	3.8 a	0.6 a	87	11.1 a	0.8 a
10	3.8 a	0.7 a	49	5.1 a	0.8 a	88	0.0 a	0.0 a
11	4.4 a	0.9 a	50	6.0a	0.7 a	89	7.9 a	0.2 a
12	5.7 a	0.8 a	51	4.1 a	0.8 a	90	14.9 a	1.2 a
13	8.3 a	1.1 a	52	3.5 a	0.7 a	91	13.7 a	1.1 a
14	6.0a	0.7 a	53	7.0a	0.8 a	92	8.6 a	0.7 a
15	4.1 a	0.8 a	54	4.8 a	0.8 a	93	8.6 a	0.8 a
16	4.4 a	1.1 a	55	7.9 a	0.7 a	94	4.4 a	0.7 a
17	1.6 a	0.6 a	56	4.1 a	0.7 a	95	5.7 a	1.1 a
18	3.2 a	0.6 a	57	3.8 a	0.6 a	96	6.7 a	0.9 a
19	4.4 a	0.4 a	58	0.3 a	0.4 a	97	12.4 a	0.8 a
20	3.2 a	0.7 a	59	6.7 a	1.1 a	98	6.3 a	0.8 a
21	4.1 a	0.8 a	60	4.8 a	0.8 a	99	10.5 a	0.8 a
22	2.9 a	0.7 a	61	3.8 a	0.7 a	100	2.9 a	1.1 a
23	4.8 a	0.8 a	62	5.1 a	0.8 a	101	1.3 a	0.6 a
24	4.8 a	0.9 a	63	6.3 a	1.0a	102	6.0a	0.8 a
25	4.1 a	0.8 a	64	6.3 a	0.9 a	103	7.9 a	0.8 a
26	8.3 a	0.9 a	65	5.1 a	0.7 a	104	5.1 a	0.7 a

27	5.4 a	1.1 a	66	5.7 a	1.0a	105	4.8 a	0.7 a
28	7.3 a	1.0a	67	9.2 a	0.7 a	106	3.8 a	0.7 a
29	4.4 a	0.7 a	68	5.4 a	0.7 a	107	5.1 a	0.8 a
30	3.5 a	0.7 a	69	10.2 a	0.8 a	108	8.3 a	0.8 a
31	5.4 a	0.8 a	70	9.2 a	1.1 a	109	4.8 a	0.8 a
32	0.0 a	0.8 a	71	8.3 a	0.9 a	110	4.4 a	0,7 a
33	6.3 a	0.7 a	72	3.8 a	0.8 a	111	4.4 a	0.9 a
34	5.1 a	1.0 a	73	4.4 a	0.9 a	112	4.1 a	0.8 a
35	3.2 a	0.7 a	74	5.1 a	0.7 a	113	5.1 a	1.1 a
36	6.3 a	0.7 a	75	4.8 a	0.7 a	114	6.0a	0.8 a
37	4.8 a	1.2 a	76	4.8 a	0.9 a	115	6.4 a	0.9 a
38	5.4 a	0.7 a	77	8.3 a	0.8 a	116	5.4 a	0.8 a
39	3.5 a	0.9 a	78	6.7 a	0.8 a			

	Blast incidence	Blast severity
LSD	9.661	1.069
CV	182.1	144.1
P	1	1

Values with the same letter are not significantly different

4.1.2 Incidence and severity of brown spot for the 64 (Biotechnology and Biological Research Council) and 116 (Korea-Africa Food and Agriculture Cooperation Initiative) rice lines in the field conditions

Brown spot incidence did not vary significantly among the rice lines. Rice lines 16, 35, and 23 had a percentage brown spot severity of over 20. Fifty-four rice lines had a brown spot severity of below 10. Line 8, 59,3,30,1,24, and 52 had a percentage brown spot severity of between 10 and 20. Few plants recorded the disease in the field, signifying that the germplasm under test was resistant to blast among the 64 rice lines (Table 4.3). Germplasm 49 recorded no brown spot incidence. Nine rice lines had a brown spot percentage incidence of over 5. The incidence of the rice lines had a greater variation from the mean of all the germplasms. Rice lines 20, 35, and 24 had a percentage brown spot incidence of over 8 percent.

In the rice plant population of the 116 rice lines, only a few plants recorded brown spots. Eighty-two germplasms had a brown spot percentage incidence of below 2. Germplasm 13 was the only germplasm with a percentage brown spot incidence of over 4. Twenty-three rice lines had a brown spot sore between 2 and 3. Among the 116 rice lines, 38 falls between a percentage of 1 and 2, while 44 rice lines were below a percentage brown spot incidence of 1. Germplasm 71 had the highest percentage brown spot severity of 19.75. Rice lines 21 and 71 are the only ones with a percentage brown spot severity of over 19. A total of 19 germplasm scored above 15 percent. Twenty-two rice lines fell below 10 percent. The remaining 75 rice lines had a percentage brown spot severity of between 10 and 15 (Table 4.4).

Table 4. 3: **I**ncidence and the percentage severity of brown spot for 64 Biotechnology and Biological Research Council germplasm

Germplasm	Brown spot incidence	Brown spot severity	Germplasm	Brown spot incidence	Brown spot severity	Germplasm	Brown spot incidence	Brown spot severity
1	0.6 a	11.1 ab	23	1.3 a	21.0 ab	45	3.5 a	7.4 ab
2	0.3 a	4.9 ab	24	9.2 a	11.1 ab	46	2.2 a	4.9 ab
3	1.9 a	7.4 ab	25	4.8 a	9.9 ab	47	0.3 a	4.9 ab
4	5.1 a	6.2 ab	26	2.9 a	4.9 ab	48	0.6 a	4.9 ab
5	2.9 a	7.4 ab	27	5.7 a	4.9 ab	49	0 .0a	0.0a
6	5.1 a	7.4 ab	28	2.9 a	6.2 ab	50	1.1a	4.9 ab
7	1.9 a	6.2 ab	29	3.8 a	7.4 ab	51	0.3 a	4.9 ab
8	3.2 a	13.6 ab	30	2.2 a	12.3 ab	52	1.9 a	11.1 ab
9	1.6 a	6.2 ab	31	0.6 a	4.9 ab	53	1.6 a	8.6 ab
10	0.6 a	4.9 ab	32	1a	9.9 ab	54	0.3 a	4.9 ab
11	1.9 a	8.6 ab	33	1.6 a	6.2 ab	55	1.3 a	6.2 ab
12	0.6 a	12.3 ab	34	1.3 a	8.6 ab	56	0.3 a	4.9 ab
13	2.9 a	4.9 ab	35	8.6 a	23.5 ab	57	0.3 a	4.9 ab
14	0.6 a	8.6 ab	36	7a	4.9 ab	58	2.5 a	6.2 ab
15	1.9 a	7.4 ab	37	1.9 a	6.2 ab	59	7.9 a	13.6 ab
16	3.8 a	25.9 b	38	6.7 a	4.9 ab	60	1.6 a	6.2 ab
17	0.6 a	8.6 ab	39	1a	6.2 ab	61	0.3 a	4.9 ab
18	12a	3.7 ab	40	4.4 a	3.7 ab	62	1.3 a	4.9 ab
19	0.3 a	3.7 ab	41	0.6 a	6.2 ab	63	1.3 a	6.2 ab
20	8.6 a	8.6 ab	42	1a	9.9 ab	64	0.6 a	4.9 ab
21	2.5 a	9.9 ab	43	2.2 a	4.9 ab			
22	1.3 a	9.9 ab	44	1.3 a	7.4 ab			
	Incidence	Severity						
LSD	7.234	161.1						
CV	335.1	11.509						
P value	0.899	0.265						

Values with the same letter are not significantly different

Table 4. 4**:** Incidence and the severity of brown spot for 116 Korea-Africa Food and Agriculture Cooperation Initiative rice lines

Germplasm	Brown spot incidence	Brown spot severity	Germplasm	Brown spot incidence	Brown spot severity	Germplasm	Brown spot incidence	Brown spot severity
1	3.5 a	12.4 a	40	1.6 a	12.3 a	79	2.5 a	17.3 a
2	1.6 a	11.1 a	41	2.9 a	14.8 a	80	0.6 a	11.1 a
3	2.5 a	14.8 a	42	1.3 a	11.1 a	81	0.6 a	8.6 a
4	2.5 a	14.8 a	43	1.0a	11.1 a	82	1.3 a	11.1 a
5	0.6 a	11.1 a	44	0.6 a	11.1 a	83	1.0 a	12.4 a
6	3.8 a	14.8 a	45	1.0a	11.1 a	84	2.2 a	14.8 a
7	2.2 a	14.8 a	46	0.6 a	8.6 a	85	0.3 a	9.9 a
8	2.9 a	16.1 a	47	0.3 a	8.6 a	86	1.3 a	12.4 a
9	2.9 a	13.6 a	48	1.0a	12.3 a	87	1:0a	13.6 a
10	2.5 a	11.1 a	49	3.5 a	18.5 a	88	0.6 a	9.8 a
11	2.5 a	14.8 a	50	1.0a	9.8 a	89	1.3 a	12.4 a
12	1.6 a	11.1 a	51	1.3 a	14.8 a	90	1.0a	13.6 a
13	4.4 a	18.5 a	52	1.6 a	13.5 a	91	1.6 a	9.9 a
14	1.9 a	13.6 a	53	1.9 a	13.5 a	92	0.6 a	14.8 a
15	3.2 a	11.1 a	54	0.6 a	8.6 a	93	2.2 a	11.1 a
16	1.6 a	11.1 a	55	1.6 a	13.5 a	94	1.3 a	18.5 a
17	1.6 a	12.4 a	56	0.6 a	11.1 a	95	3.8 a	13.6 a
18	2.5 a	16.1 a	57	1.0a	4.9 a	96	2.5 a	12.4 a
19	1.0a	14.8 a	58	1.0a	11.1 a	97	2.2 a	12.4 a
20	1.0a	16.1 a	59	2.2 a	16.1 a	98	1.9 a	13.6 a
21	3.8 a	19.8 a	60	1.3 a	16.1 a	99	3.2 a	13.6 a
22	1.6 a	13.6 a	61	2.9 a	18.5 a	100	1.6 a	8.6 a
23	2.5 a	14.8 a	62	1.0a	9.9 a	101	0.6 a	116. a
24	1.6 a	12.4 a	63	1.6 a	12.4 a	102	2.5 a	16.1 a
25	1.9 a	13.6 a	64	0.6 a	11.1 a	103	1.6 a	14.8 a
26	0.6 a	9.9 a	65	1.3 a	12.4 a	104	2.5 a	7.4 a
27	3.5 a	12.4 a	66	1.0a	13.6 a	105	1.0a	7.4 a
28	3.8 a	16.1 a	67	1.6 a	13.6 a	106	1.0a	13.6 a
29	0.6 a	8.6 a	68	2.5 a	12.4 a	107	1.0 a	14.8 a
30	2.5 a	14.8 a	69	2.2 a	17.3 a	108	1.0 a	13.6 a
31	3.5 a	13.6 a	70	1.9 a	13.6 a	109	1.9 a	13.6 a
32	1.9 a	16.1 a	71	1.9 a	19.8 a	110	1.0 a	12.4 a
33	1.3 a	9.9 a	72	2.2 a	16.1 a	111	1.0 a	8.6 a
34	0.6 a	14.8 a	73	1.3 a	13.6 a	112	1.0 a	13.6 a
35	0.6 a	9.9 a	74	1.0a	9.9 a	113	1.9 a	13.6 a
36	1.6 a	14.8 a	75	0.6 a	12.4 a	114	1.9 a	11.1 a
37	1.0a	9.9 a	76	0.3 a	11.1 a	115	1:0 a	13.6 a
38	1.3 a	13.6 a	77	0.6 a	11.1 a	116	1.3 a	13.6 a
39	1.6 a	12.4 a	78	1.0a	9.9 a			

	% B. Spot incidence	% B. spot severity
LSD	9.448	9.448
CV	79.4	79.4
P 0	0.378	0.998

Values with the same letter are not significantly different

4.1.3 Incidence and severity of blast on 40 (Biotechnology and Biological Research Council) and 100 (Korea-Africa Food and Agriculture Cooperation Initiative) rice lines in the screenhouse

Two germplasm exhibited susceptibility, scoring over four among the 40 rice lines. Blast severity differed significantly in the 40 rice lines at P<.005 (Table 4.5). At least all the rice lines got infected with a blast but at varying degrees. Nine germplasm had a score of over 3 while 13 germplasm scored less than 2. Rice lines 11, 37, and 30 had an average blast score of less than 1. A total of 13 rice lines had a blast score of less than 2. Blast infection was moderate among the germplasm ranging from few specs to mild diamond-shaped lesions in the 100 rice lines (Table 4.6). Germplasm 3 and 1 had a severity of greater than three, 51 germplasm scored over 2 of the IRRI rice blast scoring scale.

Table 4. 5: Average blast severity for the 40 Biotechnology and Biological Research Council germplasm

Germplasm	Severity	Germplasm	Severity	Germplasm	Severity
1	2.2 abc	15	3.3 abc	28	1.5 abc
2	3.3 abc	16	2.6 abc	29	2 abc
3	1.1 ab	17	2.7 abc	30	0.5 a
4	2.8 abc	18	2.2 abc	31	1.2 ab
5	4.3 bc	19	1.4 abc	32	2.5 abc
6	2.9 abc	20	2.1 abc	33	2.2 abc
7	1.4 ab	21	3.1 abc	34	2.7 abc
8	4.7 c	22	2.3 abc	35	2.3 abc
9	2.7 abc	23	1.1 ab	36	2.2 abc
10	1.0 a	24	3.5 abc	37	0.7 a
11	0.7 a	25	2.7 abc	38	2.1 abc
12	3.1 abc	26	3.5 abc	39	1.3 ab
13	1.6 abc	27	1.1 ab	40	2.3 abc
14	3.1 abc				
	LSD	1.073			
	CV	55.8			
	P	<.001			

Values with the same letter are not significantly different

Table 4. 6: Blast severity for 100 Korea-Africa Food and Agriculture Cooperation Initiative germplasm

Germplasm	blast score	Germplasm	blast score	germplasm	blast score
1	3 ab	35	2.5 ab	69	1.3 ab
2	2.9 ab	36	1.6 ab	70	2.1 ab
3	3.3 b	37	2.3 ab	71	2.2 ab
4	2.3 ab	38	2.6 ab	72	2.3 ab
5	2.8 ab	39	2.3 ab	73	2.5 ab
6	2.2 ab	40	2.5 ab	74	2.9 ab
7	2.9 ab	41	2.3 ab	75	1.3 ab
8	1.4 ab	42	2.0 ab	76	2.0 ab
9	2.6 ab	43	2.1 ab	77	1.7 ab
10	1.8 ab	44	1.8 ab	78	2.5 ab
11	2.1 ab	45	1.9 ab	79	1.1 ab
12	1.8 ab	46	1.9 ab	80	1.3 ab
13	1.6 ab	47	2.7 ab	81	2.2 ab
14	1.1 ab	48	2.3 ab	82	1.6 ab
15	1.8 ab	49	1.3 ab	83	0.9 ab
16	1.7 ab	50	2.8 ab	84	1.8 ab
17	1.7 ab	51	1.9 ab	85	1.3 ab
18	2.1 ab	52	2.3 ab	86	2.1 ab
19	1.5 ab	53	1.5 ab	87	1.1 ab
20	2.2 ab	54	1.9 ab	88	1.5 ab
21	1.8 ab	55	2.3 ab	89	2.7 ab
22	2.3 ab	56	2.4 ab	90	2.7 ab
23	2.7 ab	57	1.9 ab	91	0.8 ab
24	1.9 ab	58	1.6 ab	92	1.8 ab
25	2.4 ab	59	1.8 ab	93	1.8 ab
26	1.6 ab	60	1.9 ab	94	1.7 ab
27	1.4 ab	61	2.5 ab	95	2.1 ab
28	1.7 ab	62	1.3 ab	96	2.3 ab
29	1.3 ab	63	1.5 ab	97	2.5 ab
30	2.3 ab	64	2.1 ab	98	1.5 ab
31	1.6 ab	65	0.4 a	99	1.3 ab
32	2.3 ab	66	2.7 ab	100	2.6 ab
33	2.4 ab	67	1.8 ab		
34	2 ab	68	2.4 ab		
LSD	1.239				
CV	78.1				
P	0.004				

Values with the same letter are not significantly different

4.1.4 Brown spot severity for the 40 (Biotechnology and Biological Research Council) and 100 (Korea-Africa Food and Agriculture Cooperation Initiative) rice lines in the screenhouse

The second season recorded a higher brown spot severity which varied significantly among the different germplasms in the 40 rice lines (Table 4.7. The 100- KAFACI rice line were moderately susceptible to brown spots, all the germplasm recorded brown spots. The severity varied significantly among the different rice lines. Forty-five rice lines had a percentage brown spot severity score of between 30 and 40 (Table 4.8).

Table 4. 7: Percentage brown spot severity for the 40 Biotechnology and Biological Research Council germplasm

Germplasm	% Brown spot severity	Germplasm	% Brown spot severity	Germplasm	% Brown spot severity
1	21.5	15	37.8	29	21.5
2	24.4	16	31.1	30	11.1
3	24.4	17	31.1	31	14.7
4	25.2	18	18.5	32	25.2
5	37.0	19	13.3	33	22.2
6	36.3	20	15.6	34	28.9
7	22.9	21	34.1	35	26.7
8	14.0	22	22.9	36	29.6
9	20.0	23	10.4	37	14.8
10	9.6	24	28.9	38	23.7
11	8.2	25	31.1	39	10.4
12	26.7	26	34.8	40	23.7
13	20.0	27	17.8		
14	33.3	28	18.5		
LSD	9.819				
CV	59.4				
P	<.001				

Values with the same letter are not significantly different

Table 4. 8: Brown spot severity for the 100 rice lines of Korea-Africa Food and Agriculture Cooperation Initiative grown in a screenhouse experiment

Germplasm	Brown spot severity	Germplasm	Brown spot severity	Germplasm	Brown spot severity
1	32.8	35	35.5	68	27.5
2	27.0	36	31.8	69	23.8
3	28.6	37	29.6	70	28.0
4	34.4	38	30.7	71	31.8
5	33.9	39	37.6	72	32.8
6	34.9	40	40.2	73	46
7	46.0	41	21.2	74	48.7
8	25.4	42	22.8	75	28.0
9	34.4	43	32.3	76	28.0
10	27.0	44	33.9	77	34.4
11	28.6	45	36.5	78	28.6
12	28.6	46	25.9	79	18.0
13	30.7	47	41.8	80	20.6
14	29.1	48	34.9	81	32.8
15	25.4	49	39.7	82	25.9
16	29.6	50	31.2	83	19.6
17	32.3	51	19.1	84	24.9
18	31.8	52	27.5	85	28.0
19	27.5	53	24.9	86	29.6
20	29.1	54	30.2	87	27.0
21	29.1	55	31.2	88	26.5
22	37.6	56	29.6	89	40.7
23	31.8	57	29.1	90	34.4
24	30.7	58	22.2	91	22.8
25	36.5	59	31.2	92	32.3
26	22.2	60	25.9	93	31.2
27	24.9	61	33.3	94	29.1
28	22.8	62	27.5	95	30.2
29	32.3	63	28	96	30.2
30	31.2	64	31.2	97	31.2
31	34.4	65	20.1	98	27.5
32	33.9	66	39.7	99	26.5
33	37.6	67	29.6	100	39.7
34	37.6				
LSD	8.865				
CV	48				
P	<.001				

4.2 Evaluation of the performance of selected rice germplasm under the local environmental conditions

4.2.1 Average height (cm) and number of tillers of the 64 and 116 rice lines in the field conditions

Height was taken from day 21 after emergence, the BBSRC experiment with 64 rice lines had taller rice lines, although some were dwarf. Both height and tillers differed significantly in all the germplasms at $p<.005$. The germplasm had tillering traits as 61 rice lines had over ten tillers each. Rice lines 49, 20, and 19 had less than ten tillers. All the germplasm had a height of over 50 cm, except germplasm 49, with a height of 25.6 cm. Germplasm 31, 41, 24, and 60 are the only germplasm that recorded a height of over 70 cm. Rice lines 61, 60, 24, and 57 had tillers of 0ver 15. Germplasm 59,19, and 20 had less than ten tillers, most of the rice lines (45 rice lines) had tillers of between 11 and 15(Table 4.9).

The rice lines of KAFACI experiment with 116 rice lines were dwarf with an average of 50 cm (Table 4.10). Tillering was average in most of the germplasm. Height differed significantly among the germplasm while tillering was almost the same across the rice lines. Thirty-six rice lines had tillers of between 10 and 12. Rice lines 87,43, and 84 had a height of above 60 cm (Table 4.10). Eighty-seven rice lines had a height of over 50 cm, while 29 rice lines had less than 50 cm (Table 4.10). Height differed significantly among the 116 rice lines.

Table 4. 9: Average height (cm) and tillers of 64 Biotechnology and Biological Research Council rice lines (21 days after emergence)

Germplasm	Height	Tillers	Germplasm	Height	Tillers
1	63.9	12.6	33	65.1	11.6
2	64.1	11.3	34	56.5	11.4
3	59.8	13.3	35	63.7	13.2
4	61.5	10.4	36	65.5	10.8
5	56.6	14.2	37	63.7	11.3
6	66.5	10.8	38	57.2	11.4
7	68.0	12.1	39	63.1	10.5
8	63.6	11.1	40	59.0	14.9
9	64.8	11.7	41	70.5	12.4
10	59.2	10.5	42	65.6	12.5
11	57.4	12.9	43	59.7	14.6
12	59.1	11.2	44	56.6	12.7
13	58.2	10.9	45	64.8	10.9
14	63.2	10.4	46	62.5	14.3
15	56.0	12.5	47	60.0	10.8
16	53.4	11.2	48	55.2	11.2
17	54.0	13.4	49	25.6	6.0
18	58.0	12.2	50	65.8	12.0
19	57.1	9.1	51	67.0	11.6
20	68.3	9.0	52	60.2	14.4
21	60.0	13.9	53	67.1	13.6
22	64.7	15	54	67.2	12.6
23	66.7	12.3	55	66.2	11.6
24	71.0	16.3	56	63.9	11.4
25	65.5	11.6	57	67.7	15.5
26	69.9	14.0	58	67.2	11.2
27	65.4	10.0	59	64.2	10.0
28	69.0	10.0	60	72.4	17.7
29	198.7	12.4	61	66.9	17.4
30	64.7	14.7	62	64.9	13.1
31	70.1	13.1	63	65.0	13.2
32	65.7	12.7	64	61.8	11.9

	Height	Tillers
LSD	9.646	3.91
CV	37.2	77
P	<.001	<.001

Table 4. 10**:** Average height (cm) and tillers of the 116 Korea-Africa Food and Agriculture Cooperation Initiative rice lines

Germplasm Height	Height	Tillers	Germplasm	Height	Tillers
1	51.5	12.2	30	52.6	8.5
2	51.8	9.7	31	53.8	11.2
3	40.3	7.8	32	54.9	7.6
4	51.0	10.4	33	57.0	9.4
5	51.8	10.7	34	49.6	8.1
6	54.9	11.6	35	54.7	11.0
7	54.7	9.9	36	59.3	11.2
8	57.4	10.3	37	51.4	10.6
9	54.3	10.5	38	52.5	9.0
10	54.4	10	39	54	11.9
11	56.6	14.1	40	50.0	7.9
12	57.2	16.6	41	58.3	8.7
13	58.7	10.1	42	51.9	8.5
14	53.4	7.7	43	61.2	10.0
15	52.9	8.6	44	54	12.9
16	55.5	12.2	45	47.2	11.7
17	52.6	7.6	46	51.8	13.6
18	51.8	9.1	47	49.2	11.2
19	52.3	6.7	48	55.4	12.3
20	51.6	10.2	49	56.6	10
21	55.2	11.2	50	53.6	11.2
22	54.4	7.5	51	51	8.1
23	53.0	9.6	52	54	8.6
24	53.2	8.9	53	56.9	10.8
25	55.6	9.4	54	54	9.8
26	57.3	9.0	55	57.8	10.1
27	49.8	6.7	56	56.1	11.9
28	49.6	10.2	57	39.1	8.2
29	51.1	7.3	58	49.3	

59	51.4	12.2	88	0.0	0.9
60	55.0	7.7	89	49.7	9.9
61	54.3	9.3	90	56.2	10.9
62	53.8	8.5	91	51.1	7.9
63	41.6	5.9	92	49.5	9.0
64	47.7	8.1	93	53.1	9.3
65	53.0	8.0	94	51.3	8.2
66	49.6	6.2	95	46.2	10.4
67	48.4	12.7	96	54.3	9.3
68	51.0	8.2	97	53.6	11.3
69	49.2	8.2	98	55.7	10.4
70	51.7	7.0	99	54.3	10.8
71	51.7	8.6	100	51.2	10.4
72	43.0	8.3	101	46.8	9.2
73	47.3	8.2	102	53.6	8.8
74	52.0	9.4	103	52.4	8.9
75	48.8	8.0	104	52.9	8.0
76	54.4	8.4	105	53.8	11.2
77	54.6	9.9	106	46.3	10.7
78	57.6	10.1	107	49.7	11.2
79	51.0	9.1	108	52.7	10.2
80	50.1	10.7	109	44.1	4.6
81	50.0	9.7	110	45.6	9.0
82	52.4	9.0	111	53.9	8.1
83	51.1	8.7	112	49.8	8.9
84	60.1	9.9	113	49.2	6.6
85	49.2	10.1	114	47.4	7.9
86	56.0	9.0	115	50.1	6.4
87	61.6	7.1	116	50.6	9.2

	Height	Tillers
LSD	7.972	2.956
CV	37.1	75.6
P	<.001	<.001

4.2.2 Grain yield of rice line, 64 Biotechnology and Biological Research Council and 116 KAFACI germplasm in the field conditions

Nine germplasm in the 64 rice lines (BBSRC experiment) had a grain yield of over 10 tones per hectare while ten germplasm had their grain yield in grams ranging from 5 to 10 tones (Table 4.11). The yield for the different germplasm did not vary significantly among the different treatments.

Ten of the 116 germplasm (KAFACI experiment), had a grain yield of below 500 grams in their plots, while other ten rice had over 1000grams each plot. The rest of the germplasm had an average yield ranging from 500 to 1000 grams (Table 4.12). Rice lines 11 and 88 had no yield at all.

Table 4. 11: Grain yield in tons per acre for 64 BBSRC rice lines

Germplasm	Yield	Germplasm	Yield	Germplasm	Yield	Germplasm	Yield
1	13.9 a	17	9.1 a	33	5.8 a	49	0.0 a
2	8.8 a	18	7.024 a	34	8.7 a	50	9.6 a
3	6.2 a	19	10.4a	35	7.3 a	51	16.9 a
4	6.2 a	20	9.2 a	36	11.3 a	52	7.59 a
5	8.5 a	21	12.3 a	37	11.6 a	53	11.3 a
6	4.0 a	22	6.8 a	38	5.0 a	54	16.1 a
7	6.6 a	23	12.5 a	39	15.2 a	55	6.8 a
8	10.4 a	24	13.5 a	40	9.6 a	56	12.9 a
9	8.2 a	25	4.5 a	41	11.9 a	57	11.4a
10	6.8 a	26	9.7 a	42	12.6 a	58	12.8 a
11	6.7 a	27	7.1 a	43	11.0 a	59	14.7a
12	11.5 a	28	5.9 a	44	78.0 a	60	13.1a
13	11.4 a	29	15.7 a	45	14.1 a	61	7.1 a
14	7.0 a	30	5.5 a	46	8.3 a	62	9.7 a
15	11.2a	31	9.8 a	47	11.3 a	63	18.6 a
16	12.4a	32	10.1 a	48	9.5 a	64	11.2a
	LSD	8.853					
	CV	55.7					
	P	0.207					

Table 4. 12: Grain yield in tones per acre for 116 Korea-Africa Food and Agriculture Cooperation Initiative rice lines

Germplasm	Yield	Germplasm	Yield	Germplasm	Yield	Germplasm	Yield
1	12.4 ab	30	14.0 b	59	7.0 ab	88	0 a
2	12.1 ab	31	14.5 b	60	9.7 ab	89	11.8 ab
3	10.2 ab	32	9.8 ab	61	5.2 ab	90	11.8 ab
4	13.7 ab	33	13.4 ab	62	8.1 ab	91	10.2 ab
5	12.2 ab	34	9.8 ab	63	9.6 ab	92	10.2 ab
6	9.0 ab	35	12.8 ab	64	9.6 ab	93	12.9 ab
7	11.7 ab	36	8.6 ab	65	7.2 ab	94	10.1 ab
8	10.2 ab	37	10.8 ab	66	6.9 ab	95	12.1 ab
9	13.3 ab	38	10.9 ab	67	13.7 ab	96	7.9 ab
10	11.9 ab	39	15.4 b	68	8.1 ab	97	13.3 ab
11	0.0 a	40	11.1 ab	69	10.1 ab	98	8.3 ab
12	7.6 ab	41	9.6 ab	70	8.2 ab	99	11.8 ab
13	9.5 ab	42	9.4 ab	71	9.8 ab	100	9.4 ab
14	10.6 ab	43	12.1 ab	72	9.1 ab	101	6.2 ab
15	10.1 ab	44	12.6 ab	73	8.3 ab	102	10.1 ab
16	8.7 ab	45	12.3 ab	74	11.0 ab	103	9.5 ab
17	12.2 ab	46	12.4 ab	75	10.4 ab	104	8.0 ab
18	9.3 ab	47	11.1 ab	76	8.5 ab	105	8.8 ab
19	9.3 ab	48	14.0 b	77	10.3 ab	106	7.8 ab
20	10.8 ab	49	10.1 ab	78	10.7 ab	107	10.1 ab
21	10.5 ab	50	13.5 ab	79	10.9 ab	108	10.3 ab
22	12.5 ab	51	11.8 ab	80	11.8 ab	109	5.6 ab
23	8.8 ab	52	11.5 ab	81	9.8 ab	110	6.3 ab
24	12.3 ab	53	10.9 ab	82	12.4 ab	111	7.3 ab
25	8.4 ab	54	8.6 ab	83	5.7 ab	112	6.9 ab
26	12.4 ab	55	12.1 ab	84	11.5 ab	113	6.6 ab
27	13.7 ab	56	14.9 b	85	11.4 ab	114	7.3 ab
28	6.7 ab	57	9.8 ab	86	11.1 ab	115	5.0 ab
29	13.6 ab	58	9.2 ab	87	12.0 ab	116	7.8 ab
	LSD	6.106					
	CV	37.6					
	P	0.014					

4.2.3 Correlation of agronomic parameters of rice line to incidence, severity, AUDPC of blast and brown spot of rice in the field conditions

Table 4. 13: Correlation of agronomic parameters of rice lines to incidence, severity, AUDPC of blast and brown spot of rice.

	Height	Tillers	AUDP B. spot	Yield KAFACI	AUDP blast
Height	1				
Tillers	0.49	1			
AUDP Brown spot	0.20	0.045	1		
Yield KAFACI	0.39	0.30	-0.034	1	
AUDP blast	-0.11	-0.11	0.15	-0.10	1

0-.3, weak, 4-5 moderate, 6-.7, strong correlation, .8-.10 very strong

The height and tillers had a moderate positive correlation (r=0.5). The yield of rice also positively correlated with the height of rice (r=0.39). There was a weak negative correlation between the yield of rice and brown spot (Table 4.13). There was also a weak negative correlation between the height of rice and blast (r=-0.1). Tillers and blast had a weak negative correlation (r=-0.11).

4.2.4: Correlation of tillers, height disease incidence and severity for Korea-Africa Food and Agriculture Cooperation Initiative germplasm rice lines grown in a controlled environment

Table 4. 14: Correlation of tillers, height and AUDP Korea-Africa Food and Agriculture Cooperation Initiative season two

	Average of height	Average of Tillers	Blast score severity	Brown. Spot severity	Blast AUDPC	Brown spot. spot AUDP
Average of height	1					
Average of Tillers	-0.18	1				
Blast score severity	0.28	0.30	1			
Brown spot severity	0.36	0.26	0.59	1		
Blast A.U.D.P.C	0.23	0.36	0.98	0.56	1	
Brown spot AUDP	0.39	0.25	0.57	0.99	0.54	1

There was a very weak negative correlation between the height and tillers of rice. Correlation between height and blast score severity was positive but weak. Height and percentage brown spot severity had a moderate positive correlation. The percentage blast severity had a moderate correlation with tillering of rice (Table 4.14). Tillers had a weak correlation with percentage brown spot severity. The percentage blast score had a higher positive correlation with percentage severity of brown spot.

4.2.5: Correlation of tillers, height disease incidence and severity for BBSRC germplasm rice lines grown in a controlled environment

Table 4. 15: Correlation of tillers, height disease incidence and severity for BBSRC germplasm rice lines grown in a controlled environment.

	Brown. spot incidence	Blast incidence	blast severity	of Brown spot severity	Average of height	Average of tillers	AUDPC blast BBSRC	AUDPC Brown spots BBSRC
Brown. spot incidence	1							
Blast % incidence	0.9	1						
Blast Severity	0.69	0.71	1					
Brown spots severity	0.9	0.88	0.7	1				
Average of height	0.36	0.29	0.26	0.34	1			
Average of tillers	0.54	0.52	0.39	0.5	0.63	1		
AUDPC Blast	0.62	0.65	0.91	0.68	0.18	0.42	1	
AUDPC Brown spot	0.76	0.76	0.58	0.91	0.2	0.39	0.66	1

There was a positive correlation between the incidence of brown spot and the incidence blast (r = 0.89). Plants that are affected by the blast are also likely to be followed by a brown spot (Table 4.15). The incidence of the blast is also positively correlated with that of blast severity. Plots with a higher incidence of the blast also recorded higher severity (r=0.71). There is a weak correlation between percentage brown spot incidence, and the height of rice, the incidence of the brown spot does not severely affect the height of rice. There was a moderate correlation between the percentage brown spot incidence and the tillering of rice. Percentage blast incidence had a strong positive correlation with blast severity. The plants that recorded brown spot incidence had a higher probability of having a higher brown spot severity. Blast incidence had no significant relationship to the height of rice. There was an average relationship between the incidence of blast and the tillering of rice. The severity of the blast had a moderate relationship with the percentage of brown spot severity. Blast severity had a weak relationship with both the height and tillers of rice. The percentage of brown spot severity correlated with the height of rice, but the relationship was weak. The tillers of rice had a moderate correlation with percentage brown spot severity. There was a positive correlation between the height and tillering of rice. Rice blast did not affect yield in grams (Fig 4.1). Rice blast however affected tillers and height (Fig4.2 and 4.3)

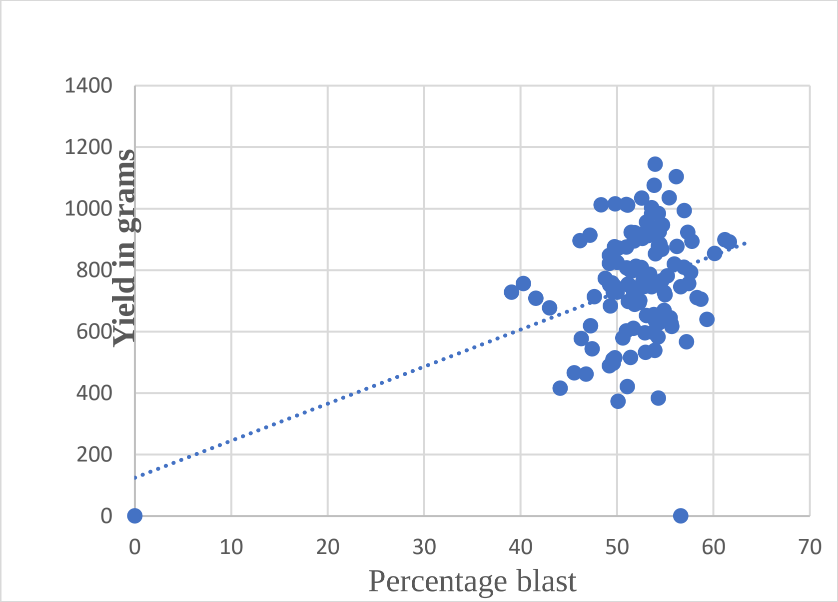

Fig 4. 1: Correlation of yield of rice and rice blast severity

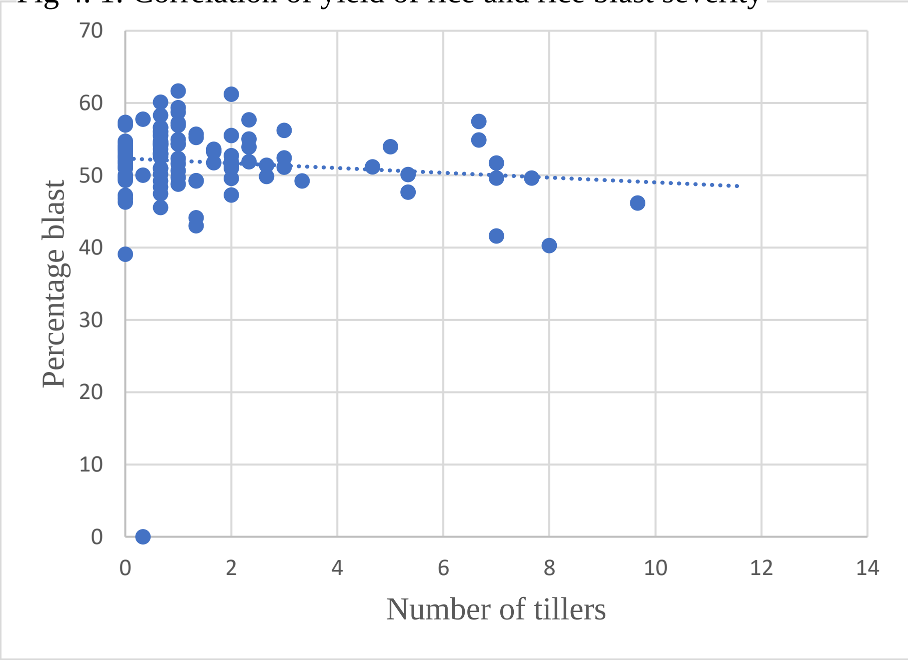

Fig 4. 2: Correlation between rice blast and tillers

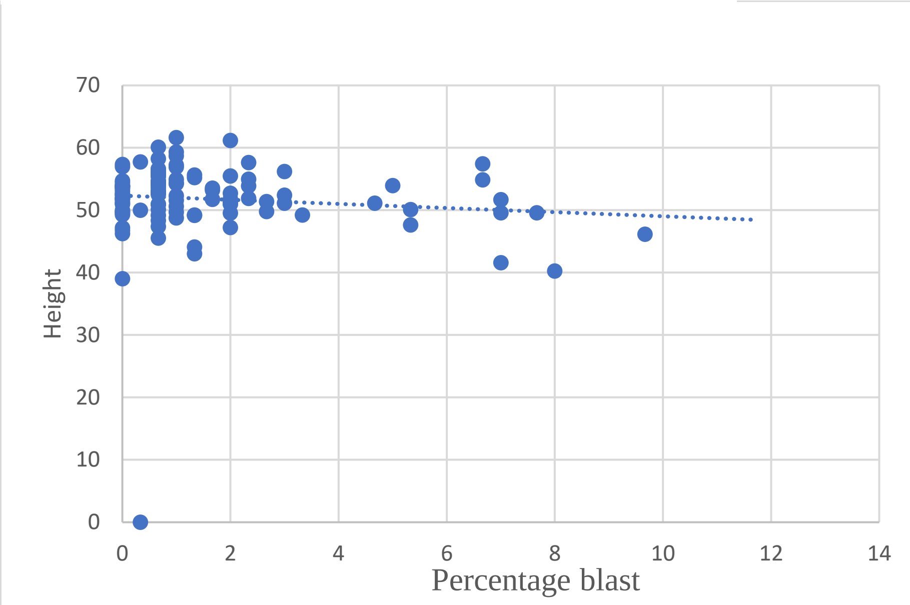

Fig 4. 3: Correlation between rice blast and rice height

4.2.6 Agronomic parameters of the Biotechnology and Biological Research Council and Korea-Africa Food and Agriculture Cooperation Initiative rice lines screenhouse environment

The 40 rice lines were not as tall as the first season planted in the field. Tillers and height varied significantly among the germplasm tested. Germplasm 5, 34,2, 22, and 1 had an average height above 50 cm. Rice line 31, 10, 30, 27, 24 and 20 were very short with a height below 20cm. The height of most of the germplasm ranged between 30 cm and 50 cm. Rice lines 15, 16, 2 and 6 had an average of more than four tillers.

Like the first season, the 100 rice lines did not grow tall, the Amount of tillering was average. Both the tillers and height varied significantly among the rice lines.

Table 4. 16: Agronomic parameters of the 40 Biotechnology and Biological Research Council rice lines

Germplasm	Tillers	Height	Germplasm	Tillers	Height	Germplasm	Tillers	Height
1	2.2	56.5	15	3.1	38.5	29	2.8	51.3
2	4	54.9	16	3.5	43.4	30	0.9	26.6
3	1.8	47	17	1.7	38.8	31	0.9	16.1
4	1.9	32.4	18	1.9	47.9	32	2.1	37.6
5	2.8	50.1	19	2.7	42.7	33	1.3	44.9
6	4.5	52.4	20	0.8	28.2	34	1.5	50.8
7	1.2	41.1	21	0.8	32.5	35	2.3	48.3
8	1.5	39.1	22	2.4	56	36	2.7	30.9
9	2.2	36.4	23	1.2	34	37	1.3	45.7
10	0.9	20.4	24	1	27.8	38	2.1	49.8
11	1.1	31.9	25	2.4	48.5	39	2.3	38.5
12	2	37.3	26	2.7	43.3	40	1.4	30.2
13	1.8	35.7	27	1.1	27.7			
14	1.9	35.9	28	2.1	49.8			

	Height	Tillers
Mean	40.03	1.966
CV (%)	32.6	46.8
P	0.003	<.001

Table 4. 17**:** Height (cm) and tillers of the 100 rice lines from Korea-Africa Food and Agriculture Cooperation Initiative experiment grown under screenhouse conditions

Germplasm	Height	Tillers	Germplasm	Height	Tillers	Germplasm	Height	Tillers
1	49.7	6.6	35	40.4	9.2	69	49.2	5.6
2	41.3	8.2	36	43.6	6.6	70	46.9	6.9
3	49.8	9	37	49.8	6.7	71	47.4	6.2
4	48.6	8.9	38	47.4	7	72	44.7	6.9
5	47.9	9.5	39	63.8	4.5	73	54.7	6.2
6	48.7		40	52.8	6.4	74	63.3	4.6
7	44.2		41	41.5	6.1	75	54.8	5.9
8	41.8	5.3	42	44.4	8	76	47	4.4
9	52.2	6.7	43	42.6	8.1	77	44.6	5.6
10	48.9	6.7	44	42.6	9	78	45.1	7.4
11	44.7	7.2	45	48.6	6.9	79	40.6	3.2
12	40.6	7.8	46	49.6	7.1	80	47.4	5.8
13	46.7	7.5	47	46.8	7.7	81	45.8	6.3
14	47.5	4.7	48	48.7	7	82	50.8	4.8
15	26.7	5.7	49	41.9	7.1	83	40.7	7.1
16	42.2	7.7	50	46.4	5.5	84	42.2	7.7
17	41.7	7	51	50.1	3.5	85	48.1	5.9
18	49.1	7	52	52.5	6.1	86	56.2	4.7
19	45.5	6.9	53	46.6	6.8	87	54.1	5.6
20	50.9	7.9	54	52.9	4.3	88	46.2	6
21	52.7	7.1	55	43.6	5.6	89	48	6.5
22	46.6	6.1	56	47.3	9.3	90	52.2	7.3
23	44.4	6	57	47.6	6.1	91	46.8	6.2
24	43.3	5	58	33.2	4.3	92	49.3	7.5
25	54.7	5.7	59	49.7	7.3	93	48	5.7
26	38.3	8	60	50	6.5	94	47.3	6.2
27	40.6	7.2	61	51.8	5.3	95	48.8	6.9
28	51.3	4.8	62	44.7	6.1	96	44.5	7
29	46.5	6.1	63	46.6	4.2	97	46.1	9.5
30	49.7	5	64	42.1	5.2	98	46.5	7.5
31	51.7	5.7	65	38.6	4.6	99	44.6	5.3
32	50.6	5.7	66	46.5	6.3	100	53.3	5.9
33	45.9	6.4	67	48.2	7.2			
34	43.4	8.4	68	43.7	6.1			

	Height		Tillers
LSD	11.07	LSD	2.661
CV	46.4	CV	80.2
P	<.001	P	<.001

CHAPTER FIVE: DISCUSION

5.1: Reaction of selected rice germplasm to blast and brown spot of rice

The average blast score indicated that the lines were resistant to both rice blast and brown spot of rice. This is attributed to the resistance that was introjected into the rice lines through a breeding program on new rice for Africa (NERICA), the field was not inoculated with any blast pathogen. Rice fields often experience mild rice blast but farmers at least get a meaningful harvest. Zelalem *et al.,* in 2017 screened NERICA lines in Uganda and found five of the genotypes to be resistant to rice blast (Lamo *et al.,* 2021), which were in congruent with results of Kumar in 2019. In the experiment none of the germplasm was immune but most displayed resistance which was also reported by (Lamo *et al.,* 2021). The disease may be higher during some periods but do not occur regularly when the environment has shifted to favor the development of the disease

All the germplasm were grown in the same environment but had differing disease rates due to their varied reaction to blast. Rice Blast was minimum in the field as it was planted with many ascensions together that possess various blast resistance genes as also reported by Ghimire *et al.,* in 2019. The rice lines exhibited resistance to blast apart from a few that were moderately susceptible. The disease was not very intense to adversely impact the yield. The different rice lines showed a varying degree of blast resistance. The 116 rice lines had a lower blast rate when compared to 64 rice lines as they were mostly composed of ascensions from Korea-Africa Food and Agriculture Cooperation. The lines were resistant, with a few showing mild susceptibilities.

Disease incidence was recorded on less than 10% of the total population of plants per plot and all the germplasm had at least an incidence of the blast as the disease appeared not to spread fast from one plant to the next. Blast was trapped from the environment by the spreader rows planted with a susceptible Basmati 370 and introduced in the rice lines under test. Other infections arose from seed infections (Raveloson *et al.,* 2017). The infection began with a tiny pinpoint spec that kept expanding. After four to five days, the spec took a diamond shape and was brown in color. Data in this study has evidence that rice blast resistance is present in many different germplasms, which can be identified and placed in high-yielding ascension to reduce the impact of the disease on the yield. Development and progression of the lesions due to blast occurred from the third week to the booting stage, where no further disease progression occurred due to adult resistance (Krattinger *et* *al.*, 2015). Only a few lesions were observed on each leaf, with some leaves not having lesions. This is because the environment was not conducive for the pathogen, causing the blast to multiply and cause secondary disease cycles.

The disease did not infect older plants, especially after the formation of the panicles. This is because the leaves had already developed thick cuticles that the rice pathogens find challenging to penetrate as reported by Garroum *et al.*, in 2016. Resistance was also associated with anthocyanins in most rice lines identified by the pigmentation of the leaves and stems of the rice lines. The lesions expanded but then were limited after some time, hence there was no coalescing, making the disease not severe. According to Asibi *et al.*, in 2019, the ascensions that were able to increase photosynthesis in their remaining healthy parts of the leaves after infection with blast did not suffer much loss. The combined effect of resistance in the rice line and unfavorable weather conditions suppressed the occurrence and spread of blast in the 64 and 116 rice experiments.

Its, however, not clear if resistance was the reason why blast was lower in the field; disease escape might have occurred due to unbalanced factors that lead to an epidemic, i.e., presence of a virulent pathogen, susceptible host, and conducive environment. Unexpected blast outbreak can happen when the three factors balance well in the future; hence several experiments ought to be carried out at different weather and climatic conditions which have other races of the blast pathogen to confirm the finding.

Brown spot manifested itself as tiny but many brown specs on the affected leaves, which became tan in color expanding in size (Elliott, 2020). The spots were evenly distributed on all the leaves of affected plants. All the rice lines recorded brown spot incidence cases apart from rice line 49 in the 64 rice lines. The disease did not spread aggressively because only a few plants per plot were spotted with brown spots. The severity of the brown spots in the two experiments was mild across the growing period implying that the rice lines had good resistance to the brown spot. All the rice lines had a similar response to the effect of brown spot, $P < 0.378$ for percentage brown spot incidence and $P < 0.998$ for percentage brown spot severity, respectively. This is because all the lines had been bred for resistance against both blast and browns pot using the vast number of brown spot resistant germplasm (Ota *et al.*, 2021). Some rice lines like number 21 showed susceptibility to brown spots despite having the resistance to browns pot. The lesions for the brown spot did not coalesce to cover the whole leaves. The experiment revealed that genes confer resistance to brown spots found in different rice lines that can be identified and pyramided in rice lines with desirable characteristics like yield and aroma but are susceptible to brown spots. Mizobuchi *et al.,* in 2016 did a similar screening test for brown spot resistance genes in 24 rice lines and found 2 out of 24 rice lines to possess to the resistant genes while six of the ascensions were moderately resistant.

5.2 Agronomic and yield performance of the selected rice lines

Tillering of rice plants began ten days after emergence, and maximum tillering happened 50 days after emergence which is important trait to observe when gauging productivity of rice. Optimum productivity was achieved when rice obtained the optimum number of productive tillers. According to Wang et al., in 2022, the number of tillers produced can affect the size and quality of the grains it produces, and can also influence plant health and disease resistance. The better the tillering capability, the greater the potential for higher yields and healthier plants. Therefore, tillering can play a major role in the productivity of a rice crop. When tillering began, nearly all the nodes were still compressed and closer to the ground. Tillering stopped when plants reached panicle initiation. Tillering marked the end of the seedling stage; secondary tillers grew from the primary tillers to fill the whole plant. The different rice lines had different tillering capacities. Both the primary and secondary tillers produced panicles at the end of the growing season. The weak and unhealthy tillers did not form any panicle when they matured.

Numerous studies have been conducted to evaluate the agronomic and yield performance of selected rice lines, Sadimantara et al in 2021 did a trial to test yield performance of double haploid rice lines and found that yield was greatly affected by both environment and genotype. These research efforts have provided valuable insights into the genetic and environmental factors influencing rice yield potential. High-yielding rice lines have shown improved agronomic traits such as increased tillering ability, disease resistance, and lodging resistance, leading to enhanced productivity (Hirano et al., 2017). Researchers worldwide have contributed significantly to the study of agronomic and yield performance in rice, utilizing various research approaches. Breeding programs have focused on developing rice lines with enhanced yield potential, disease resistance, and stress tolerance. These efforts have resulted in the release of several high-yielding rice varieties, contributing to increased rice productivity in different.

High-yielding rice lines contribute to increased rice production, meeting the growing demand for food in the face of a growing global population. This helps ensure food security and reduces the risk of food shortages. High-yielding rice lines significantly increase farmers' incomes by producing larger yields per unit of land (Saber et al., 2021). This improves livelihoods, alleviate poverty, and uplift rural communities by providing economic stability. High-yielding rice lines often exhibit improved resource use efficiency, including nutrient uptake, water utilization, and land productivity. This enhances the sustainability of rice production and reduces the environmental impact by minimizing the use of fertilizers, irrigation water, and land.

The rice lines with a higher blast also had a higher incidence of browns pot because the same conditions that favor the development of brown spots are the same for the blast. Rice lines that recorded a higher blast incidence also had a higher blast severity as rice blast is a polycycle disease-producing more inoculum from the primary lesions (Asibi *et al.,* 2019). Brown spots affected the height of rice because the spots for brown spots interfered with the typical plant physiological processes like photosynthesis. Percentage brown spot significantly reduced the tillering of the rice line as a result of the effect. As the percentage of brown spot incidence increased, its severity also rose because more inoculum was produced. Higher blast incidence reduced the number of tillers made in all the rice lines. The taller plants also had more tillers which signified that the plants were doing well. There was a negative correlation between blast and both height and tillers where the agronomic parameters reduced as blast increased.

The regression between brown spot and yield gave a negative gradient where brown spot negatively affected the yield. The regression equation can predict yields in a given field when one has data about the current status of the brown spot. The regression equation was Y=2.18(%Brown spot AUDP) +783.4. According to research done by Aryal *et al.,* 2016, results showed that neither severity of brown spot or AUDP had any significant relationship with the yields of rice which was in contrast with my finding.

5.3: Conclusion

1. The study demonstrated that rice lines markedly differed in resistance to a brown spot and blast diseases rice and could still be used in breeding for resistance to the foliar diseases of rice. NERICA rice lines are able to tolerate blast and brown spot diseases of rice allowing farmers to have a meaningful harvest. The genetics of resistance should however be established for their practical use. Breeding for resistance will require the genes that code for important anatomical traits like pigmentation and thick cuticle in the germplasm to be identified and added to the high yielding cultivars. Blast disease at mild levels was also not found to have a significant effect on the agronomic and yield performance of the rice lines.

2. The severity of brown spot disease rice had a significant negative impact on the height of the rice crop. Tillering was also severely affected, rice blast disease of rice also reduced on the number of tillers generally affecting the performance of the rice crop. There was a negative correlation between blast and both height and tillers where the agronomic parameters reduced as blast increased

5.4: Recommendations

i. The 25 lines that were resistant ought to be adopted by rice farmers in the effort to reduce yield losses that results from the two foliar diseases of rice. Emphasize on the selection and development of rice lines with durable resistance to ensure long-term effectiveness.
ii. Rice farmers should adopt the nine rice lines that had good agronomic parameters like tillering and height because of the higher yields as observes in the field experiment.
iii. Further research on the yield performance of the germplasm that are resistant to blast and brown spot of rice need to be done to come up with the germplasm that are both resistant and high yielding

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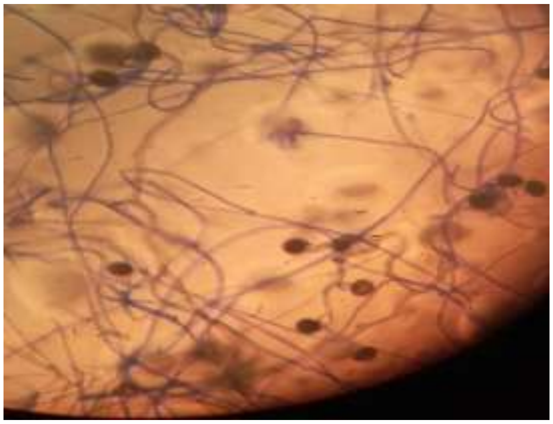
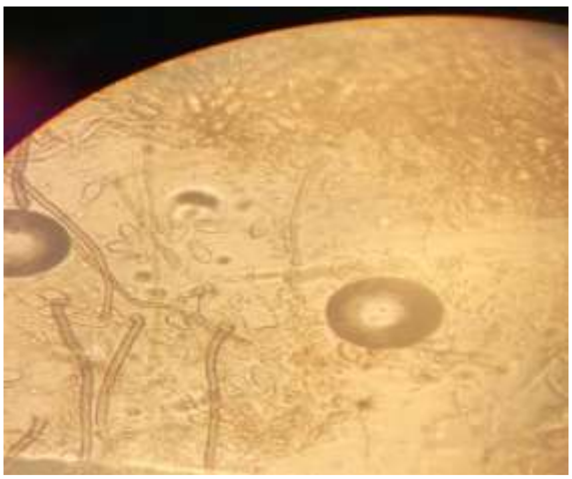
APPENDICES

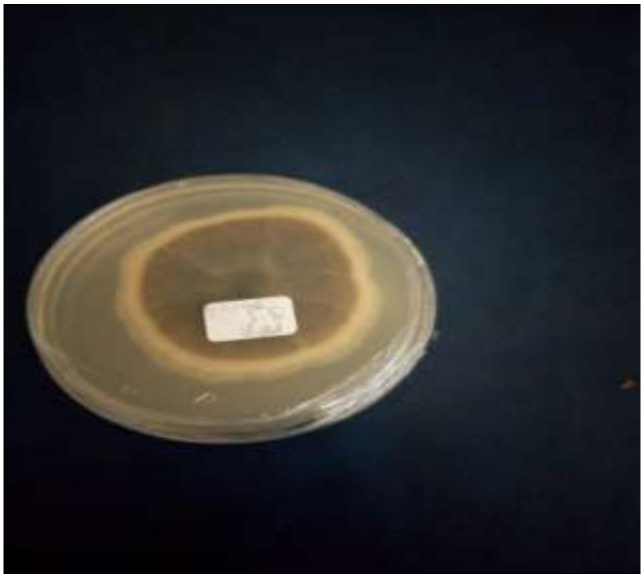


Appendix 1. 1:Ascospores of *Magnaporthe oryzae* from culture



Appendix 1. 2: Conidia for *Magnaapporthe oryzae*

Appendix 1. 3: Front view of the culture for *Magnaporthe oryzae*



Appendix 1. 4: Backview of *Magnaporthe oryzae* culture

Appendix 1. 5: Front view of *Magnaporthe oryzae* culture

Appendix 1. 6: Conidia for *Cochliobollus miyabeanus*

Appendix 1. 7: Front view culture for *Magnaporthe oryzae*

Appendix 1. 8: Screenhouse experiment

Appendix 1. 9: *Magnaporthe oryzae* from the seed.

Appendix 1. 10: Field experiment

Appendix 1. 11: Regression between blast and yield

ANOVA

	Df	SS	MS	F	Significance F			
Regression	1	41939.2	41939.2	1.12337	0.29144			
Residual	114	4256019	37333.5					
Total	115	4297958						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	763.301	22.4184	34.048	1.43E-61	718.89	807.712	718.89	807.712
Average of AUDP blast	-9.5729	9.03196	-1.0599	0.29144	-27.465	8.31936	-27.465	8.31936

Appendix 1.12

Appendix 1. 12: Regression between brown spot and yield

ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4823.68	4823.68	0.12809	0.72108
Residual	114	4293134	37659.1		
Total	115	4297958			

Appendix 1. 13: T and P values from regression between brown spot and yield.

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	783.429	97.7295	8.0163	1.05E-12	589.828	977.03	589.828	977.03
Average of AUDP brown spot	-2.1779	6.08536	-0.3579	0.72108	-14.233	9.87713	-14.233	9.87713