INTEGRATED MANAGEMENT OF SHEATH BLIGHT DISEASE OF RICE

By

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DEPARTMENT OF PLANT PATHOLOGY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

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DECLARATION

I hereby declare that this thesis entitled **"Integrated management of sheath blight disease of rice"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other university or society.

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We, the undersigned members of the advisory committee of **Mr. Prasad V.R (2012-11-198)** a candidate for the **Master of Science in Agriculture**, with major field in **Plant Pathology**, agree that the thesis entitled **"Integrated management of sheath blight disease of rice"** may be submitted by **Mr. Prasad V.R** in partial fulfilment of the requirement for the degree.

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PRASAD V.R.

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Introduction

1. INTRODUCTION

Rice is the staple food of more than 65 per cent of global population and it occupy 11 per cent of total cropped area in the world. It is grown in an area of 153.5 million hectares with a total production and productivity of 614.6 million tonnes and 4 tonnes per hectare respectively at world level. India ranks first in area (44.6 m ha) and second in rice production (116 mt) next to China (176 mt) (F.A.O, 2006). It is the most important food crop in densely populated countries of Asia, particularly Bangladesh, China, India, Indonesia, Iran, Japan, Korea, Pakistan and Sri Lanka. About 80 per cent of calorific intake of people in these Asian countries is derived from rice.

India, despite having the maximum area under rice cultivation in the world, several factors responsible for low quality rice are unfavourable weather conditions, natural calamities, socio-economic problems, soil factors, lack of suitable varieties, poor seed quality, use of untreated seeds, less availability of agro-chemicals, non-adoption of modern production technologies and most importantly the losses caused by weeds, insect pests and diseases (Naidu, 1992).

Several diseases have been found to occur in rice crop resulting in extensive damage to grain and straw yield. The crop is subjected to attack by many diseases caused by fungi, bacteria, viruses, nematodes and several physiological disorders, causing annual loss to the tune of 12 to 25 per cent of the total production. Rice is subjected to the attack of over 30 fungi in India (Rangaswami and Mahadevan, 1999).

Among the diseases, sheath blight caused by *Rhizoctonia solani* Kuhn which was earlier considered to be a minor disease is now regarded as globally important one. It is second only to and often rivals the blast disease, especially after the popularisation of high yielding varieties since 1960. It is an important soil borne disease distributed worldwide and cause significant yield loss in rice.

The peculiar versality of subterranean nature of *R. solani* and prolonged survival of sclerotia in rice stubbles and in soil, render the disease management less effective. Due to the hazardous nature of some chemicals used in agriculture and the possibility of getting toxicity in food chain, farmers prefer integrated strategies for management of pests and diseases. In recent years, wider use of liquid organics and lesser use of new generation fungicides for disease management are gaining importance. The concept of food habit has changed in such a way that, consumers have now become more health conscious and started spending on quality foods.

Several organic products have proven their usefulness against a number of pathogens. Liquid organic manures *viz.,* Panchagavya, Jeevamrutha, Beejamrutha, Angara, Vermiwash, etc. are rich sources of antagonistic microbes and act as disease control sprays (Ramanathan, 2006). At the same time, several new generation fungicides developed are comparatively safer, environment-friendly and highly specific to the target pathogen, even at very low concentrations and are harmless to the crops.

In this backdrop, the present research programme was carried out to develop an integrated management strategy for sheath blight disease, which includes characterization of sheath blight pathogen *R.solani* and studies on the efficacy of vermicompost, liquid organic formulations and new generation fungicides.

The research programme entitled "Integrated management of sheath blight disease of rice" envisaged the following objectives:

1. Survey, collection and isolation of different isolates of *Rhizoctonia solani* from disease prone areas of Thrissur district, Kerala state.

2. Characterization based on cultural and morphological characters of collected isolates.

3. Symptomatology of the disease.

4. Preparation of liquid organic formulations *viz.,* Panchagavya, Dasagavya and Jeevamrutha and estimation of their microbial profile.

5. *In vitro* evaluation of the liquid organic formulations and new generation fungicides against different isolates of *R. solani.*

6. Conducting field experiments for the integrated management of sheath blight using liquid organic formulations, new generation fungicides and vermicompost against sheath blight disease of rice.

Review of Literature

2. REVIEW OF LITERATURE

2.1. Occurrence of sheath blight disease

Sheath blight was first reported in Japan by Miyake (1910) as a new disease under the name, 'Oriental sheath blight and leaf spot' and the causal organism was identified as *Sclerotium irregulare*. Sawada (1912) made detailed studies and reported the causal organism to be identical with *Hypochnus sasakii.* Since then, its occurrence has been reported from various parts of the world. In Philippines, Reinking (1918) and Palo (1926) reported a similar disease. Park and Bertus (1932) reported sheath blight disease from Sri Lanka and referred the organism as *Rhizoctonia solani.* Subsequently it was reported from China (Wei, 1934) and from USA (Ryker and Gooch, 1938). Sometime it was considered to be a disease of the Orient, but it was also reported from Brazil, Surinam, Venezuela and Madagascar (Ou, 1985). Prevalence of sheath blight has been recorded in most of the rice growing countries of the world like Bangladesh, China, Columbia, Cuba, Germany, Indonesia, Iran, Japan, Korea, Malaysia, Moscow, Netherlands, Nigeria, Philippines, Senegal, Sri Lanka, Taiwan, Thailand, Trinidad, Tobago and Vietnam (Dasgupta, 1992).

In India, Butler (1918) had mentioned the occurrence of this disease for the first time. The first detailed report of sheath blight in India was made by Paracer and Chahal (1963) from Gurdaspur in Punjab. Subsequently the occurrence of this disease was reported from other locations of Punjab (Kohli, 1966), Uttar Pradesh (Singh and Pavgi, 1969) and from West Bengal (Amin *et al*., 1974). In Kerala, the incidence of sheath blight was first noticed at Regional Agriculture Research Station, Pattambi in Palakkad district by Prabhat (1969). Soon several outbreaks were reported from many parts of the state resulting in considerable damage. Since then it was considered as the most important disease of rice in Kerala wherever rice is grown, irrespective of the seasons. Surveys conducted by Gokulapalan (1981) in rice fields of Vellayani, Karmana, Adoor and Kayamkulam of Kerala state revealed that besides rice, *R. solani* could infect a

number of common weeds and on crops like Groundnut and Daincha grown in rice fallows. Thus *R. solani* remains in the soil across the season perennially.

2.2. Yield loss

In Japan, about 1.2 to 1.9 lakh hectares were reported to be infected by sheath blight, inflicting a loss of 24,000 to 38,000 tonnes of rice every year (NIAS, Japan, 1954). A yield loss to the tune of 25 per cent was reported by Hori (1969) when the disease reaches upto the flag leaves. In Philippines, losses due to sheath blight varied from 30 to 40 per cent and reported up to 100 per cent in endemic areas (Ou, 1985). A moderate estimation of losses due to sheath blight alone in India has been up to 54.3% (Rajan, 1987; Roy, 1993). Losses in crop production due to sheath blight ranged from 1 to 50 per cent, and were dependent on inoculum amount, crop growth stage, environmental condition and varietal resistance (Groth *et al.,* 1991; Marchetti and Bollich, 1991). Yield losses of 5-10 per cent have been estimated from tropical low land rice in Asia (Savary *et al.,* 2000). According to Kumar *et al.* (2009), sheath blight is one of the deadliest diseases of rice in terms of economic concern that cause up to 25 per cent yield loss.

2.3. The pathogen

Sheath blight of rice is caused by *Rhizoctonia solani* Kuhn (*Thanatephorus sasakii* (Shirai) Tu and Kimbrough). Much confusion prevailed regarding the name of the teleomorph of the fungus. It was often referred as *Hypochnus sasakii* Shirai and *Thanatephorus cucumeris* (Frank) Donk etc., in literature. Sawada (1912) reported *Sclerotium irregulare* to be identical with *Hypochnus sasakii.* In the Philippines, Reinking (1918) and Palo (1926) reported a similar disease which is caused by the fungus of *Rhizoctonia* group. The perfect stage of the fungus, *Corticium sasakii,* was reported from the IRRI, Philippines and described as *Thanetephorus cucumeries* (Anon, 1972).

The fungus is commonly known by the sclerotial state of *R. solani* Khun, as sclerotia are abundantly produced on the affected sheath and lamina of rice leaf and also in soil. Duggar (1915) described in detail about the morphology and growth habit of the fungus and stated that the young hyphal branches inclined in the direction of growth and were invariably constricted at the point of union with the main hyphae. Fredericksen *et al.* (1938) measured the sclerotia of *R. solani* and recorded the size ranging from one to seven mm in diameter. There are three types of sclerotia, namely host sclerotia of the smallest size, soil sclerotia of the medium size and laboratory sclerotia of the largest size (Gangopadhyay and Chakrabarthi, 1979).

2.4. Symptomatology

Ou (1985) described the symptoms as follows: the disease appear as spots on the leaf sheath which are first ellipsoid or ovoid, long and greenish grey in colour. The centre of the spots turn greyish white with brown margins. Sclerotia are formed on or near these spots, but are easily detached. The size and colour of spots and the formation of sclerotia depend upon environmental conditions. Under humid conditions, the mycelium of the fungus may grow over the surface of the leaf sheath and can spread to a considerable distance within 24 h. In the field, the spots are usually initiated near the water level. When conditions are favourable, the infection spreads to the upper leaf sheaths and on leaf blades. The presence of several larger spots on a leaf sheath usually causes the death of the whole leaf and in severe cases all the leaves of a plant may be blighted in this way. It is not unusual in the tropics, to find most of the leaves of the affected rice plant killed by the fungus. According to the report of IRRI, Philippines, when rice leaves were infected by sheath blight, the mycelium covered the entire infected area and the fungus was found to produce two types of mycelium; the straight running type and the lobate type (Anon, 1972).

The spots on the leaf sheath are first ellipsoid or ovoid, about ten mm long and greenish grey. These spots enlarge and may reach 2-3 cm in length and

become irregular in outline. The centre of the spots becomes white with brown or purplish margins depending on the host variety. Many such spots become confluent giving a characteristic banded appearance. Outer leaves may fall off; plants look yellow and may ultimately wilt. Under favourable weather, infection may spread up to the culm, killing the entire leaves on the surface of the lesions and sometimes on the inner surface of the sheath and on the culms; brownish silky wefts of mycelium are present. These wefts produce brown or dark brown sclerotia, which eventually fall on the ground. It is the banded appearance and presence of the sclerotia which gives the name "banded sclerotial disease" to such disease caused by *Rhizoctonia solani* (Singh, 2005).

2.5. Characterization of *R.solani* isolates

The first systematic grouping of *R. solani* based on anastomosis (hyphal fusion) had made by Richter and Schneider (1953). Chien and Chung (1963) reported 300 isolates of *R. solani* from Taiwan and inoculated on 16 rice cultivars. Based on pathogenicity, the isolates were classified in to seven cultural types and six physiological races. Parmeter *et al.* (1969) grouped *R. solani* into four groups namely AG1, AG2, AG3 and AG4 which are genetically isolated and incapable of nuclear exchange due to non-fusion between isolates of different groups. Tu *et al.* (1979) studied many strains from Taiwan and noted that the strains with less aerial mycelium were more pathogenic. Yu (1975) stated that sclerotia from rich media were highly pathogenic. Floating and sinking sclerotia may have differential roles in pathogenicity due to variation in membrane permeability as proposed for *Macrophomina phaseolina* (Gangopadhyay and Chakrabarthi, 1979).

Vijayan (1986) grouped 41 isolates of *R. solani* from Kerala into four morphological groups MG1, MG2, MG3 and MG4. In these, MG1 infected rice and was corresponded with AG1 of United States. At present at least 12 anastomosis groups (AG-1 to AG-11 and AG-B1) of *R. solani* with distinct physiology and genetic composition have been reported (Carling *et al.,* 1987). Hyakumachi *et al.* (1988) revealed *R. solani* as a complex pathogen having great

variation among the isolates, in terms of mycelial colour, zonation, type and number of sclerotia and pathogenicity. Dasgupta (1992) reported that basidiospores are 2-4, terminal in perfect cymose or racemose clusters formed by branching of short celled ascending hyphae.

Meena *et al.* (2001) studied the morphological and cultural characteristics of *R.solani* isolates of Madurai, Melur, Coimbatore, Trichy and Arumbanur of Tamil Nadu state in relation to their virulence on rice. Among the five isolates of *R.solani* tested for their virulence, Madurai isolate was the most virulent one by exerting the maximum lesion height of 66.4 per cent on rice plants on artificial inoculation. The mycelial and sclerotial characters of *R.solani* varied greatly among the isolates. Madurai isolate grew faster and produced dark brown mycelium. Larger sized and dark brown sclerotia were produced by Madurai isolate, whereas small, light brown sclerotia were produced by Trichy isolate. The number and size of sclerotia were found to be the largest in Madurai isolate. Potato dextrose agar medium supported the maximum mycelial growth and sclerotial production while the minimum mycelial growth and sclerotial production were found in Czapek's Dox medium.

Singh *et al.* (2002) characterized 46 isolates collected from two fields of Dehradun and Nagina in Uttar Predesh based on their cultural and morphological characteristics, anastomosis behavior, aggressiveness and Random Amplified Polymorphic DNA (RAPD). All the isolates were multinucleate and shared typical characteristics of *R. solani*. They all belonged to AG-1IA although they exhibited either 2 (incompatible fusion) or 3 (compatible fusion) type anastomosis reaction with the tester isolate belonging to AG-1IA. Even morphologically dissimilar isolates exhibited 3 type of anastomosis reaction. Population of *R. solani* was highly diverse with respect to the above characteristics. The genetic variation was related with the distribution of the isolates in different climatic regions as environment might be influencing pathogenic variability that is evident by clustering of majority of Dehradun and Nagina isolates in sub-clusters I and II respectively.

Basu *et al.* (2004) collected sheath blight infected rice samples from different locations of West Bengal *viz.,* R1 (Mashuri: Burdwan, Dist), R2 (IR 36), R3 (IR 50), R5 (Jaya: all from Chinsurah Dist. Hooghly), R7 (Saket 4 : Pandua, Dist. Hooghly), R9 (Pankaj Arambagh Dist. Hooghly), R11 (IR 36 : Howrah Dist.) and R12 (Jaya, Bhangar Dist). Aerial growth was luxuriant (R12) to abundant (R1, R5, R7, R9 and R11) in most isolates. It was moderate in R2 and sparse in R3. Growth was oppressed in all the isolates and varied from wooly (R1, R2, R3 and R9) to cottony (R5, R7, R11 and R12). Colony colour ranged from creamy (R5 and R7) to light brown (R1, R2, R3, R9, R11 and R12). Sclerotia were not differentiated in isolates R3 and R5. Sclerotial production was poor in isolates R1 and R7, fair in R12 and good in R2, R9 and R11. Sclerotial size was largest in R9 and smallest in isolate R2. Disease severity was lowest in seedlings inoculated with isolates R3 and R5 and highest in those inoculated with isolates R9 and R11. The hyphal width of isolates R2 and R7 averaged 5.0 and 5.9 mm, respectively. Width of other isolates averaged between 6.4 and 7.5 mm. No anastomosis occurred between isolates R1-R2, R2-R3, and R3-R9. Between R1-R3, R1-R5, R1-R12, R2-R5, R2-R9, R2-R12, R3-R7, R3-R11, R5-R9, R5-R11, R7-R11 and R9-R12, hyphal tip attraction and attachment was observed, but no fusion occurred.

Sharma *et al.* (2005) characterized 24 isolates of *R.solani* collected from several locations of North India *viz.,* Solan, Shimla, Kullu, Ludhiana and New Delhi by using morphological and molecular markers and variation were observed in hyphal cell size. Seventeen isolates were produced few to abundant, white to dark brown or black, small to larger sclerotia, generally in the middle of the colony. Genetic variation was also analysed by using 11 Random Amplified Polymorphic DNA primers (RAPD), four Universal Rice Primers (URP) and two Inter Simple Sequence Repeat (ISSR) markers and finger print pattern generated for each isolate.

Guleria *et al.* (2007) collected 19 isolates of *R. solani* from various regions of Punjab and studied their morphological and pathological characters. Majority

of the isolates were fast growers with raised and fluffy colonies and hyphal width of 9.6 µm, while four exhibited moderate growth rate. Colony colour in all except the two isolates was light yellowish brown. Sclerotial number per 5.0 mm culture disc of the test isolates ranged between 2.1 and 11.2 mm; their size varied between 1.31 and 2.08 mm. Sclerotial colour in all, except two isolates were dark brown and most of them were found scattered in the colony. There was no relationship between morphologically similar isolates and their pathogenic behavior. Majority of the isolates produced lesion length between 45.6 and 58.2 mm on detached rice leaves. Molecular characterization of genetic diversity in the test isolates was studied by using ISSR and RAPD markers, analysed with UPGMA, resulting five clusters with 49-89 per cent genetic similarity. Most of the isolates showed grouping, specific to the host variety.

Kumar *et al.* (2008) studied on the morphological and virulence of 25 isolates of *R.solani* collected from different regions of Uttar Pradesh (India), such as Azamgarh, Basti and Faizabad. Among the morphological characters, variation was observed in hyphal growth, distribution, colour, size and weight of sclerotia. Most of the isolates were fast growers having dark brown mycelium with macro-sized sclerotia distributed throughout the medium with the average weight ranging from 0.04 to 0.82 mg. A few isolates had off-white mycelium with sclerotia distributed near the inoculation point. Virulence diversity of the isolates were analysed on ten rice cultivars under *in vivo* and found that, in most of the isolates, the symptoms appeared in 48 h of inoculation, but in some other isolates disease was appeared at 96 h of inoculation, The disease severity was analysed by Area Under Disease Progress Curve (AUDPC) value, on the basis of lesion length and observed that most of the isolates were moderately virulent, some were highly virulent and a few of them were less virulent. Comparative analyses of *R.solani* isolates indicated that fast growing isolates with macro-sized sclerotia were highly virulent compared to slow growers with micro-sized sclerotia. Rice cultivars, NDR-359 and Ajaya depicted highly resistant disease reaction with most of the isolates, whereas the variety Swarna depicted highly susceptible reaction. Lal and

Kandhari (2009) studied morphological variability *viz.,* colony size, mycelial growth, colour and formation of sclerotia (central, peripheral or scattered), location (aerial or surface) and texture of sclerotia (smooth or rough) among the 25 isolates of *R.solani* collected from different rice growing areas.

Goswami *et al.* (2012) studied cultural characters of *R. solani* at different temperatures and pH levels. The maximum growth rate of mycelium of isolates was found at 30°C.At 35°C the isolate GAZ-9 and GAZ-18 showed initiation of growth, but the rate was very slow. The optimum temperature for sclerotial production of the isolates GAZ-9, JES-16, GAZ-18 SYL-26 was 30°C and for the isolate DIN-8 was 25°C. The optimum pH for maximum radial growth was six for DIN-8 and seven for other four isolates. The maximum number of sclerotia was produced by DIN-8, GAZ-9, and SYL-30 at pH 8, 4, and 7 respectively. The optimum pH for sclerotia formation in JES-16 and GAZ-18 was pH 6.

Jayaprakashvel and Mathivanan (2012) studied morphological and pathological variations of 236 south Indian isolates of *R. solani* inciting rice sheath blight obtained from 45 locations. Sclerotial features such as colour, size, shape and distribution pattern were varied among the isolates. Majority of *R. solani* isolates were fast growers and they attained complete mycelial growth within two days and the emergence of sclerotial structures was seen even in four days of incubation. Selected ten *R. solani* isolates exhibited considerable variations in pathogenicity on three different rice cultivars.

Kuiry *et al.* (2013) collected 67 isolates of *R. solani* associated with rice, maize, sugarcane, weeds, cabbage, pointed gourd, water melon, potato and bean from different agro-ecological region of West Bengal (WB). Cultural and morphological characteristics revealed considerable diversity among the *R. solani* isolates. Cultural and morphological analysis of WB isolates of rice indicated that the diversity among the isolates does not correlate with their origin. On the basis of morphological characters, *R. solani* isolates could be easily separated from *R. oryzae -sativae* isolates. The number of sclerotia, hyphal length, weight of

sclerotia and growth rate of the pathogen are the important morphological markers for differentiation of *R. oryzae-sativae* from *R. solani* isolates.

2.6. Integrated disease management

Many attempts have been made in the past to manage sheath blight disease by various methods including physical, biological and chemical methods.

2.6.1. Physical Methods

Prabhat *et al.* (1971) studied the viability of sclerotia of *R. solani* in different soil depths and suggested that the viability was not influenced by the depth under dry conditions. However, he observed that viability was lost at deeper layers of more than ten cm by providing a submerged condition for more than two months. Hashiba and Mogi (1973) observed that in uncultivated fields, there were marked reduction in the number of sclerotia and their loss in germination was observed as time passed, indicating the importance of fallowing in sheath blight management. Prabhat *et al*. (1974) suggested that flooding the rice field for a period of two to three months after harvest, helped to lose the viability of sclerotia indicating the importance of flood fallowing in disease management. Tu *et al.* (1979) indicated that when sclerotia in the surface of the field survived for more than sixteen months, those buried at depths of two cm survived only for a period of less than eight months. Alexander (1987) conducted field experiments and revealed that deeper ploughing followed by submergence of soil for a period of two months reduced the infestation of sheath blight in rice.

2.6.2. Organic amendments

Kannaiyan and Prasad (1981) reported reduction in seedling infection of rice by *R. solani* by the application of neem cake. Devi *et al.* (1982) reported complete inhibition of mycelial growth and sclerotial germination of *R. solani* with *Cymbopogon flexuosus* oil, at 0.4% concentration. Kannaiyan and Prasad (1983) reported that application of *Azadirachta indica* as green manure reduced

the infection of sheath blight pathogen. Banerjee *et al.* (1989) observed that oil from *Azadirachta indica* at five per cent concentration inhibited the sclerotia germination of *R. solani* isolated from rice. Oil extracted from *Pongamia glabra* at five per cent concentration inhibited the germination of sclerotia of sheath blight pathogen (Mishra and Tewari 1990). Garg and Siddiqui (1992) reported that caryophyllene and eugenol from the leaves of *Ocimum sanctum* exhibited antifungal activity against *R. solani.*

Irobi (1992) reported antimicrobial activity of *Chromolaena odorata* which contains alpha pinene (18.8%), beta pinene (10.5%) and pregei jerene (14.3%) and exhibited antifungal activity against *R. solani*. Ganguly (1994) reported that water extract of the leaves of *O. sanctum* had antifungal activity againast *R. solani*. Application of subabul (*Leucaena leucocephala)* decreased the incidence of *R. solani* in soil. Sundarraj *et al.* (1996) reported that plant extracts of *Allium sativum, Prosopis juliflora, Gymadropsis pentaphaylla, Leucosaspera* and Gingelly oil cake showed inhibition of growth of sheath blight pathogen. Neem cake at 150 kg ha^{-1} was most effective treatment in reducing disease incidence and severity caused by sheath blight pathogen *R. solani* (Meena and Muthusamy, 1999). Khoa *et al*. (2011) found that foliar spraying and seed soaking of extracts of either fresh or dried leaves of *Chromolaena odorota* gave up to 68 per cent reduction in sheath blight under controlled and under field conditions.

2.6.3. Biological methods

The history of biological control dates back to 1908 when Potter showed that plant pathogens could be inhibited by their own metabolic products. Garrett (1956) defined biological control of plant diseases as any condition under which or practice whereby survival or activity of a pathogen is reduced through the agency of any other living organism except man by himself with the result that there is a reduction in the incidence of the disease caused by the pathogen.

Hino (1935) noticed *Rhizoctonia solani*, the causal agent of sheath blight of rice was incorporated into a loamy soil, the pathogen was destroyed within five days by *Bacillus lactis* and *Trichoderma lignorum* which was the native flora of that particular soil. Endo (1973) suggested the possible use of *Neurospora crassa* to control sheath blight of rice as the disease incidence was markedly reduced by *Neurospora crassa* in soil while seedling growth was not affected. Roy (1977) observed the efficiency of *Trichoderma viride* as a biocontrol organism against *R. solani* and observed that when *R. solani* was grown in combination with *T. viride*, the mycelial growth and sclerotial germination of the former became detrimental.

In vitro studies by Gokulapalan and Nair (1984) indicated that *Aspergillus niger* and *T. viride* inhibited linear growth of *R. solani* while certain bacterial isolates reduced the germination of sclerotia. Rabindran and Vidhyasekaran (1996) studied the inhibitory effect of *Pseudomonas fluorescens* isolated from rhizosphere of different crops against *R. solani.* One of the most effective strains identified by them was PfALR2, as an antibiotic resistant strain and a peat-based bacterial biocontrol formulation was developed and were highly effective in managing sheath blight of rice. The effective dose of a peat formulation was assessed for seed treatment, seedling root dip, soil application and foliar spray. All individual treatments were also found effective in controlling sheath blight of rice. According to Das *et al., (*1998) *Trichoderma viride* was found to be more effective than *Bacillus subtilis* in reducing sheath blight infection of rice.

Das and Hazarika (2000) found that *T. harzianum* was more effective than *T. viride* in reducing sheath blight infection with increased yield. Nandakumar *et al.* (2002) tested *P. fluorescens* strains PF1, FP7 and PB2 against *R. solani* and to be highly effective in inhibiting the pathogen. Grosch *et al.* (2006) evaluated broad spectrum fungal antagonists obtained from soil and identified *Trichoderma reesi* and *T. viride* as potential bio control agents against *R. solani*. Guifang *et al*. (2006) obsorved 83.5 per cent inhibition of mycelia of *R. solani by* the fungus *Helmenthosporium gramineum f.sp. echinochloae* (HGE) and the culture filtrate of HGE also showed 84.1 per cent inhibition of *R. solani*. (Surendran *et al*., 2011)

isolated different strains of *P. fluorescens* from different locations of Kuttanad in Alleppey district of Kerala for screening against rice sheath blight disease. Singh (2013) evaluated the different application methods of *T. harzianum* and *P. fluorescens*-27, and their potential against sheath blight of rice under glasshouse conditions and found that maximum reduction in disease severity (40.5%) and incidence (58.9%) was recorded when *T. harzianum* applied as a combined delivery system as seeding root tip + foliar spray, followed by same combination of *P. fluorescens*-27 in reducing disease severity (35.0%) and incidence (54.9%).

2.6.4. Liquid organic formulations

Panchagavya was tested for different crops such as turmeric, paddy, onion, gingely, sugarcane, banana, vegetables and curry leaf and was found to enhance growth, vigour of crops, resistance to pest and diseases and the keeping quality of vegetables and fruits (Natarajan, 2000). Xu (2001) reported that Panchagavya is rich in Effective Microorganisms (EM). EM could synthesize phytohormones *i.e.,* auxins and other growth regulators that stimulated growth of maize crop, EM contained proactive substances that could significantly affect leaf stomatal response in maize. Leaf stomata of the EM treated maize opened more rapidly than water treated control plants and when leaves were subjected to dehydration, the stomata closed more slowly (*i.e.,* remained open longer) thus showed that, EM contained bioactive substances that could have significantly affected leaf stomata response and led to increased Leaf Area Index (LAI).

A combination product of biogas slurry with Panchagavya is adjudged as the best organic nutrition for sustainability of maize-sunflower-green gram system by its overall performance on growth, productivity, quality of crops, soil health and economics. This product is the mixed culture of naturally occurring, beneficial microbes mostly lactic acid bacteria (*Lactobacillus*), yeast (*Saccharomyces*), actinomyces (*Streptomyces*), photosynthetic bacteria (*Rhodopseuedomonas*) and certain fungi *(Aspergillus)* and improved the soil

quality, growth and yield of sweet corn, which was equal to or higher than what was obtained from chemical fertilizers (Somasundaram *et al*., 2007).

Mohanalakshmi and Vadivel (2008) revealed that when ashwagandha plants were sprayed with Panchagavya (3%) it produced higher number of leaves per plant. Vennila and Jayanthi, (2008) revealed that application of 100% recommended dose of fertilizer along with Panchagavya spray (2%) significantly increased the okra plant height (131.7 cm) and dry matter production (5.90 g plant^{-1}). Sumangala and Patil (2009) evaluated the efficacy of Panchagavya in controlling grain discolouration in rice growing tracts of Tungabhadra project area and Upper Krishna Project area of Karnataka state comprising Raichur, Koppal and Gulbarga districts. As the pathogen *Curvuleria lunata* was dominated in grain discoloration, major experiments were conducted with *C. lunata.* Efficacy of unique combination of by-products of cow, Panchagavya and the individual products were tested on effect of spore germination and mycelial growth of *C. lunata.* Panchagavya recorded highest inhibition (95%) followed by the individual products, cow urine (85.67%) and the remaining individual components, ghee (85.56%) ranked next followed by milk (84.23%), cow dung (84.10%) and curd (79.10%). Three different concentrations of Panchagavya (1, 3 and 5%) were also tested against *C. lunata* and maximum inhibition (86.30%) of *C. lunata* was recorded with five per cent followed by one per cent and three per cent. Seed treatment with Panchagavya recorded the highest germination per cent (90.70) and vigour index (1036.36) as compared to control.

Microbial load and different nutrient status of Panchagavya and Jeevamrutha were estimated by Sreenivasa *et al.* (2011). Total bacteria, fungi and actinomycetes in Panchagavya and Jeevamrutha were raged from (20.4-26.1 x 10^5 cfu/ml), (13.8-18.0 x 10^4 cfu/ml) and (3.6-4.2 x 10^3 cfu/ml) respectively. In addition, microbes like nitrogen fixers and P- solubilizers (2.7-5.0 x $10^{2)}$ and (3.6-4.2 x 10^2 cfu/ml) respectively were also estimated from these organic formulations. Nutrient status indicated the presence of major nutrients like

nitrogen (770-1000 ppm), phosphorous (166-175 ppm), potassium (126-194 ppm) and minor nutrients like zinc (1.27-4.29 ppm), copper (0.38-1.58 ppm), iron (29.7-282) and manganese (1.8-10.7).

Panchagavya, a vedic formulation for increased productivity, disease resistance and as biofertilizer was tested on various pulses like *Vigna radiate, Vigna mungo, Arachis hypogea, Cyanopsis tetragonoloba. Lablab purpureus, Cicer arietinum* and on cereal, *Oryza sativa* var. ponni and observed highly beneficial results (Tharmaraj *et al.* 2011). Sireesha (2013) conducted field trails in Nellore (Andhra Pradesh) for control of blast disease in rice. The treatments were: Neem seed kernel extract, Neem cake, Neem oil, Panchagavya, *Pseudomonas fluorescens, Trichoderma viride* and *Pongamia pinnata.* All the treatments showed significant control over against the pathogen.

2.6.5. Chemical method

Chemical control of sheath blight has been attempted by many workers all over the world. Hashioka and Saito (1953) reported that arasan at dilutions of 1 in 1000 to 1 in 25000 was effective in controlling *Corticium sasakii.* Chen and Chien (1961) reported that banded sclerotial disease was best controlled by 1:3000 tuzet with 0.8 per cent lime w/w or by 4:8 Bordeaux mixture plus 0.1 per cent Granosan, applied 45-50 days after transplanting in the first crop season and 40-45 days in the second crop season. Hashioka (1956) reported that methoxy methyl mercury chloride and ethyl mercury phosphate were moderately effective in preventing sheath blight infection. Hashioka (1961) tested five organo mercurials, three organo sulphar and four organo arsenical fungicides against the sheath blight pathogen by direct dipping of hyphae on infected culms in Petri dishes and found that organo arsenicals were highly effective than ethyl mercurials.

Laboratory assay of fungicides against *Rhizoctonia solani* has been attempted by several workers. Sinclair (1960) reported that isolates of *R. solani* differed in their sensitivity to Captan, PCNB and Dichlone. Elsoid and

Sinclair (1963) reported that *R. solani* isolated from seedling cotton became tolerant to PCNB, Captan, Dichlone, Maneb and Thiram after seven serial transfers on potato sucrose agar containing these fungicides. Abeygunawardena and De Silva (1964) reported that natural infection by *Corticium sasakii* was reduced by organo arsenic sprays (Ziram + methyl arsine-bis-di-methyl-dithiocarbamate) at 0.1 to 0.2 per cent and to a lesser extent by dodine at the same concentration of dithiocarbamate, ferbam, was better than maneb; while copper oxide and oxychloride were inferior to the organic compounds in controlling sheath blight of rice.

Chen and Chein (1961) reported methyl arsine sulphide was effective when applied at late tillering as a spray at 100 to 200 ppm or as a dust 1 part in 300 parts of the active ingredient against this disease. *In vitro* studies conducted by Muneera (1973) and Mathai (1975) revealed that Captan and Dithane M-45 were ineffective against *R. solani.* Captafol and Carboxin at 200 ppm each were found to be effective against the sheath blight pathogen *in vitro* (Dash and Panda, 1984). Among the four systemics and sixteen non systemics tested *in vitro*, Bavistin, Dithane M-45, BAS 3050 F, Benlate, Captan and RH 893 were effective against *R. solani* even at 100 ppm. Kataria and Grover (1977) observed the inhibitory effect of Bavistin on the mycelial growth of *R. solani* in Czapek's agar plates. Delen and Yildiz (1982) studied inhibitory effect of four isolates of *R. solani* in media containing Carbendazim (1.5 mg/ml). All the three isolates could be inhibited by the fungicide Carbendazim.

Jaganmohan (1977) found that Vitavax and Benlate were effective in inhibiting the growth of *R. solani* at concentrations of 500 ppm and above in the laboratory. It was found that Hinosan at 100 ppm and above was very effective in inhibiting the growth of *Rhizoctonia solani*. Gokulapalan (1981) studied the efficacy of fungicides minerals, nutrients and nematicides against *R. solani* revealed that combined application of fungicides Vitavax (0.1 %) or Fycop (0.4%) along with the nematicide carbofuron (Furadan 3G) significantly reduced the sheath blight intensity and considerably increased the grain yield. Kannaiyan and Prasad (1984)

recorded Benlate and Hinosan to be highly effective. Telan and Tapsis (1986) reported that Iprodione and Benomyl were found to reduce the sheath blight in rice and field trials with IR - 50, sheath blight was controlled by Validamycin.

Das (1986) conducted *in vitro* evaluation of fungicides against *R. solani* and revealed that Ediphenphos at 100 and 250 ppm, Carbendazim at 750 and 1000 ppm, Carboxin at 750 and 1000 ppm, kitazin at 500, 750 and 1000 ppm were effective in checking the radial growth of the fungus. However, Topsin-M 70 WP (Thiophanate Methyl) applied as two foliar sprays at 50 and 65 days gave best net returns. Mishra *et al., (*1989) reported that spraying Carbendazim and Mancozeb at panicle initiation, heading and grade-1 disease stages, effectively controlled sheath blight infection in rice.

Konishi *et al.* (1990) reported that the fungicidal compound associated with the chromate (4-oxo-4H-1-benzopyran) family showed promising activity against *R. solani* under *in vitro* and *in vivo* conditions where no phytotoxicity was found to host. Kalpana (1992) opined that fungicides such as captafol, tridemorph, edifenphos and carbendazim were found to be effective against the sheath blight pathogen. Izadyar and Bardaran (1993) reported that Iprobenfos, validamycin, Iprodione and Carbendazim were found effective against *R. solani.* Tiwari (1997) reported a significant control of sheath blight by the application of Hexaconazole and was better than Edifenphos. Ahmed *et al.* (1998) tested seven fungicides in field experiments in Bangladesh and found that Propiconazole and (Thiophanate Methyl + Thiram) gave best control of rice sheath blight disease.

Chahal *et al.* (2003) managed sheath blight of rice by using eight fungicides and found that Propiconazole (0.1%) minimized the disease to the maximum extent followed by Edifenphos (0.1%), Iprodione (0.3%) and Carboxin (0.2%). Dantre *et al.* (2003) reported a few non-conventional chemicals Pyruvic acid, Zinc sulphate, Para amino acid and Benzoic acid effectively checked the growth of *R. solani. Kumari and Niza (2005)* reported the effectiveness of Propiconazole 0.75 ml/L under field condition in controlling sheath blight of rice.

Kandhari *et al.* (2005) studied efficacy of O, O-diaryl O-ethyl phosphorothionate compounds at different concentrations against sheath blight and all compounds found to inhibit the growth of *R.solani.* Bag (2009) evaluated the efficacy of a new fungicidal consortium, (Trifloxystrobin 25% + Tebuconazole 5%) 75 WG in West Bengal by conducting field experiments in kharif season of two consecutive years (2006 to 2007) using the most popular and susceptible variety 'Swarna' (MTU 7029) at R.R.S Chinsura. It was found that under high disease pressure (84.33%), the fungicidal consortium, (Trifloxystrobin 25% + Tebuconazole 5% 75 WG) was the most effective in reducing disease severity (37.61%) over control, but was at par with the antifungal antibiotic, Validamycin 3 L (38.3%). Percentage increase in yield due to the new fungicide was 50% higher over control whereas in Validamycin 3 L treated plot, 42.5 per cent increase over control was noticed. Same fungicide was also proved as the best or was at par with leading fungicide triazole in managing the sheath blight disease at several centres under All India Co-ordinated Rice Improvement Programme.

Lenka and Bhaktavatsalam (2011) evaluated new fungicides *viz.,* Azoxystrobin 25SC (0.75 and 1.0ml/litre), Flusilazole 40EC (0.6ml/litre) and Epoxyconazole 75 EC (3.0 ml/litre) against sheath blight disease and observed that Azoxystrobin 25 SC @ 1.0 ml/litre significantly reduced the disease intensity (86.50%), followed by spraying with standard fungicide Validamycin 3L @ 2.5 ml/lit. Bhuvaneswari and Raju (2012) conducted field trials at Regional Agriculture Research Station, Maruteru Andhra Predesh during kharif 2010 and 2011 to evaluate the efficacy of another fungicide consortium Azoxystrobin 18.2% + Difenoconazole 11.4% at four dosage rates of 0.75 ml/l, 1.0 ml/l, 1.25 ml/l and 2.5 ml/l along with other treatments *viz*., Azoxystrobin 23% SC, Difenoconazole 25% EC , Kitazin 48% EC, Iprodione 25% + Carbendazim 25% WP and Hexaconazole against sheath blight of rice. Lowest disease incidence was recorded with the fungicide consortium Azoxystrobin 8.2% + Difenoconazole 11.4% SC at 1.25 ml/l (9.36%) followed by 1.0 ml/l (16.43%) when compared to untreated control where the disease incidence was 72.09%. Another fungicide

combination Iprodione 25% + Carbendazim 25% WP also recorded significantly lower disease incidence of 57.33%. Johnson *et al.* (2013) studied the efficacy of Hexaconazole 5SC against sheath blight disease of rice, at different doses viz., 500, 1000, 1500 and 2000 ml ha^{-1} and found that sheath blight was effectively by all the field trials, of which the Hexaconazole 2000 ml ha^{-1} was superior and lowest incidence of 3.0, 5.73 and 11.33 per cent in the first, second and third trials respectively. This treatment also recorded maximum yield of 3000 and 2800 kg ha^{-1} in the second and third trials.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled 'Integrated management of sheath blight disease of rice' was done at the Department of Plant Pathology, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala during the year 2012-2014. The experimental materials and the methodologies of the study are given below:

3.1. Survey on the occurrence of sheath blight in rice growing locations in Thrissur district of Kerala

Purposive sampling surveys were conducted during August-September 2013 in rice growing areas of Thrissur district of Kerala to study the occurrence of sheath blight. Ten locations *viz.,* Mannuthy, Chirakekode, Ollukkara, Vellanikkara, Pattikkad, Madakathara, Chalakudy, Adat, Pudurkara and Irinjalakuda were selected for the study. From each location, three paddy fields were selected and three plots in each field having an area of one square metre were selected at random. For assessing the Per cent Disease Incidence (PDI), the number of infected plants and total number of plants in each field were recorded. The PDI was calculated using the formula,

$$\text{PDI} = \frac{\text{Total no. of infected plants}}{\text{Total no. of plants observed}} \times 100$$

From each plot, five plants were labeled and disease reactions were scored based on the Standard Evaluation Systems (SES) of Rice (IRRI, 1996) as depicted below:

Sl. No.	Description (Per cent lesion spread)	Grade/ scale
1	0	0
2	1-20	1
3	21-30	3
4	31-45	5
5	46-65	7
6	> 66	9

Per cent Disease Severity (PDS) was calculated using the formula suggested by Wheeler (1969).

$$PDS = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves observed X Maximum disease grade}} X\,100$$

Based on the PDS values, the disease reactions were categorized as described below:

PDS	Category
0	Highly Resistant (HR)
1-10	Resistant (R)
11-25	Moderately Resistant (MR)
26-50	Moderately Susceptible (MS)
51-75	Susceptible (S)
> 75	Highly Susceptible (HS)

3.2. Collection, isolation and naming of different isolates of *Rhizoctonia solani*

The infected sheath, stem and leaf portions showing typical symptoms of sheath blight were collected from ten different locations of Thrissur district. The samples were brought to the laboratory and washed under running tap water to remove dirt particles. Small bits of infected portions along with some healthy portions were surface sterilized with one per cent sodium hypochlorite solution for 30 seconds and were washed in three changes of sterile water and then transferred to sterile Petri plates containing solidified Potato Dextrose Agar (PDA) medium. The plates were incubated at room temperature (26±2 °C) and observed for the growth of pathogen from next day onwards. The pure cultures of the isolates were maintained by repeated sub culturing on PDA slants.

Isolates were assigned code numbers like ShMTY 1, where, 'Sh' denotes sheath blight, 'MTY' refers to the location 'Mannuthy' from where it was collected and '1' refers to the serial number of isolate. Likewise, the other nine isolates were also named after the location and the details were recorded.

3.3. Pathogenicity test

Pathogenicity of the ten isolates of *R. solani* was proved by inoculating them under *in vitro* condition on healthy rice plants of a highly susceptible variety - Jyothi (PTB-39) at the active tillering stage. Artificial inoculation of the isolates was done by placing actively grown mycelium on Potato Dextrose Agar (PDA) along with one to two sclerotia, in between the sheath and culm of the rice plants. The inoculated areas of the plants were covered with moistened cotton and tied with cotton thread. The plants were covered with polythene bags. Humidity was maintained by sprinkling sterile water inside the bag twice a day. The plants were observed for the development of typical symptoms up to ten days. The pathogens were reisolated from the artificially inoculated plants and compared with the original isolates.

3.4. Symptomatology

3.4.1. Symptomatology under natural condition

Symptoms developed under natural condition on sheath, tillers and leaves of rice plants at late tillering stage were recorded during the survey at various locations.

3.4.2. Symptomatology under artificial condition

To study the symptomatology of sheath blight disease under artificial condition, the different isolates were inoculated separately at the maximum tillering stage on the susceptible variety, Jyothi (PTB-39) and the symptoms developed on the sheath and tillers were recorded.

3.5. Characterization of different isolates of *R. solani*

3.5.1. Cultural and morphological characters of different isolates of *R. solani*

The mycelial characters *viz.,* colour of mycelium, texture, mycelial type, and sclerotial characters *viz.,* initiation and maturation of sclerotia, number of sclerotia per plate at 10, 15 and 20 Days After Incubation (DAI), weight of 50 sclerotia, sclerotial distribution and exudation rate of sclerotia were studied on four different media, *viz.,* Potato Dextrose Agar (PDA), Czapek (Dox) Agar (CDA), Richard's Agar (RA) and Rose Bengal Agar (RBA). The growth rate of the ten isolates on the four different media was also studied. For this, discs of ten mm diameter were cut from the actively growing cultures of the *R. solani* isolates and were placed at the centre of the Petri dish. The Petri dishes were incubated at room temperature (26 ± 2° C) and the growth rate was measured by recording the colony diameter at 24 h interval till any one of the plates attained full growth.

The cultural and morphological characters of ten isolates of *R. solani* were compared with Euclidean co-efficient and was clustered by the Unweighed Pair

Group Average Method (UPGMA) devised by Sneath and Sokal (1973) using NTSYS pc 2.02 software. The dendrogram was constructed accordingly and the cultural similarity matrix was computed.

3.6. Preparation of various liquid organic formulations

The liquid organic formulations *viz.,* Panchagavya and Dasagavya were prepared as per the procedure outlined by Package of Practices (PoP) Recommendations (*Adhoc*) for Organic Farming: Crops – KAU (2011) with slight modification. Jeevamrutha was prepared as per the procedure outlined by Palekar (2006) with slight modification.

3.6.1. Panchagavya

Panchagavya was prepared by using five by-products of cow *viz.,* cow dung, cow urine, milk, curd and ghee in the ratio of 5:3:2:2:1 + ripened and mashed palayankodan banana (one portion). All the ingredients were thoroughly mixed with a wooden ladle in a plastic bucket and were kept under shade. The formulation was covered with muslin cloth, stirred daily twice and kept for 21 days.

3.6.2. Dasagavya

Dasagavya is the mixture of Panchagavya and five plant extracts. As the first step, Panchagavya was prepared as mentioned in 3.6.1. Extracts of five plants *viz., Pongamia glabra, Leucaena leucocephala, Chromolaena odorota, Tephrosia purpurea* and *Crotalaria juncea,* which are known for their antimicrobial activity against *R. solani,* were prepared by soaking in cow urine at 1:1 ratio and kept for ten days. Then the plant extract was filtered through muslin cloth and poured into the prepared Panchagavya. The formulation was thoroughly mixed with a wooden ladle in a plastic bucket and kept under shade. The bucket was covered with muslin cloth and the contents were stirred daily twice and kept for 25 days.

3.6.3. Jeevamrutha

Jeevamrutha was prepared by using cow dung, cow urine, jaggery, cowpea powder and water at the ratio of 10:5:1:1:100. For preparation of ten litres of Jeevamrutha, cow dung 1 kg, cow urine 500 ml, jaggery 100 g, cowpea powder 100 g and water ten litres were mixed well with wooden ladle in a plastic bucket and kept under shade. The formulation was covered with a muslin cloth and was stirred daily twice and kept for 25 days.

3.7. Estimation of microbial profile of liquid organic formulations at different intervals

Total microflora of the three liquid organic formulations *viz.,* Panchagavya, Dasagavya and Jeevamrutha were quantitatively estimated by serial dilution plate technique (Johnson and Curl, 1972). Rose Bengal Agar, Nutrient Agar and Ken Knight's Agar (Appendix I) media were used for estimating the total microflora *viz.,* fungi, bacteria and actinomycetes at dilutions of 10^{-4} , 10^{-5} and 10^{-7} respectively . Enumeration of *Pseudomonas* spp. was done in King's B medium. Representative samples of the liquid organic formulations were drawn at 25, 60, 90,120 and 210 Days After Preparation (DAP) and were used for enumeration of microbial profile.

3.8. Management of sheath blight of rice

3.8.1. *In vitro* evaluation of liquid organic formulations against different isolates of *R. solani*

Inhibitory effect of the liquid organic formulations *viz.,* Panchagavya, Dasagavya, Jeevamrutha and *P. fluorescens* (Biocontrol check) were studied by poisoned food technique against different isolates of *R. solani*. The details of the treatments are given below:

Liquid organic formulations		
SI.No	**Name**	**Concentration**
1	Panchagavya	2% and 3%
2	Dasagavya	2% and 3%
3	Jeevamrutha	10 % and 20%
4	*P. fluorescens* (Biocontrol check)	2%

Liquid organic formulations were prepared and filtered through double layered muslin cloth. The required quantity of the liquid organic formulations were added to the conical flasks containing 100 ml PDA medium to get the specific concentrations, mixed well and poured into sterile Petri dishes. Mycelial discs of ten mm diameter were placed at the centre of each Petri plate. Three replications were maintained for each treatment along with control. The per cent inhibition of growth was calculated using formula,

$$\text{Per cent inhibition} = \frac{C - T}{C} \times 100$$

Where, C= Colony diameter in the control (cm)

T= Colony diameter in the treatment (cm)

3.8.2. *In vitro* evaluation of new generation fungicides against different isolates of *R. solani*

Inhibitory effect of five new generation fungicides *viz.,* Kresoxim methyl 44 SC, Pencycuron 25 SC, Flusilazole 40 EC, (Iprodione 25 WP + Carbendazim 25 WP) , Propiconazole 25 EC (Fungicidal check) were studied by poisoned food technique against different isolates of *R. solani*. The details are given below:

New generation fungicides			
SI.No	**Chemical Name**	**Dosage**	**Concentration**
1	Kresoxim methyl 44 SC	1.0 ml/L	0.1%
2	Pencycuron 25 SC	1.5 ml/L	0.15 %
3	Flusilazole 40 EC	1.5 ml/L	0.15%
4	(Iprodione 25 WP + Carbendazim 25 WP)	1.5 g/L	0.15%
5	Propiconazole 25 EC (fungicidal check)	1.0 ml/L	0.1%

Solutions of the new generation fungicides were prepared at the specific concentration mentioned above, added to conical flasks containing 100 ml sterilized molten and cooled PDA medium and mixed well. After pouring in to sterile Petri plates, ten mm mycelial discs were placed at the centre of the Petri plates. Three replications were maintained for each treatment along with control plate. The per cent inhibition of growth was calculated as mentioned in 3.8.1.

3.9. Field experiment for the management of sheath blight of rice

A field experiment was laid out to evaluate the liquid organic formulations, new generation fungicides and vermicompost against sheath blight. The details of the experiment are given below:

Variety : Jyothi (PTB- 39)

Design : RBD

Treatments : 17

Replication : Three

Plot size : 3x2 m

Spacing : (10x10) cm

Treatments:

T1	Panchagavya 3% at 45 & 60 DAT
T2	Jeevamrutha 20% at 45 & 60 DAT
T3	Flusilazole 40 EC (0.15%) at 45 & 60 DAT
T4	(Iprodione 25WP + Carbendazim 25WP) (0.15%) at 45 & 60 DAT
T5	Vermicompost @ 2.5 t/ha as basal
T6	Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP + Carbendazim 25 WP) (0.15%) at 45 & 60 DAT
T7	Vermicompost @ 2.5 t/ha as basal +Jeevamrutha 20% at 45 & 60 DAT
T8	Vermicompost @ 2.5 t/ha as basal + Flusilazole 40 EC (0.15%) at 45 & 60 DAT
T9	Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP+ Carbendazim 25 WP (0.15%) at 45 & 60 DAT
T10	Panchagavya 3% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT
T11	Panchagavya 3% at 45 DAT + (Iprodione 25 WP + Carbendazim 25 WP) (0.15%) at 60 DAT
T12	Jeevamrutha 20% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT
T13	Jeevamrutha 20% at 45 DAT + (Iprodione25WP + Carbendazim 25WP) (0.15%) at 60 DAT
T14	Effective Microorganisms 1% at 45 & 60 DAT
T15	*Pseudomonas fluorescens 2%* (Biocontrol check) as per PoP (KAU)
T16	Propiconazole 25 EC (0.1%) (Fungicidal check) at 45 & 60 DAT
T17	Control

*Vermicompost was applied as basal dose @ 2.5 t/ ha, in place of green manure.

* DAT – Days After Transplanting

3.10. Observations recorded

3.11. Disease reaction

The observations on Per cent Disease Index (PDI) and Percent Disease Severity (PDS) were recorded from five hills taken from four different corners and from the centre of the plot at 75 DAT. The PDI and PDS were calculated as mentioned in 3.1.

3.12. Effect of different treatments on biometric characters

3.12.1. Growth characters

3.12.1.1. Plant height

The height of five hills in each treatment was measured from the base of the plant to the tip of the top leaf at 75 DAT. The mean height was computed and expressed in cm.

3.12.1.2. Number of productive tillers

The numbers of productive tillers were counted from one square metre area of each treatment at 75 DAT.

3.12.2. Yield attributes

3.12.2.1. Number of panicles / hill

The number of panicles were counted from one square metre area of each treatment after emergence of panicles.

3.12.2.2. Number of spiklets/panicle

The number of spiklets of five randomly selected panicles was taken and the mean was calculated and expressed as number of spiklets / panicle at the time of harvest.

3.12.2.3. Number of filled grains/ panicle

The number of filled grains of five randomly selected panicles was taken and the mean was calculated and expressed as number of filled grains/panicle at the time of harvest.

3.12.2.4. Thousand grain weight

One thousand grains were collected at random, from the produce of each plot and their weight was recorded in grams.

3.12.2.5. Grain yield

The grains from each plot, after winnowing and cleaning, were weighed and grain yield was computed at 13 per cent moisture and expressed in kg/ha.

3.12.2.6. Straw yield

The straw from each plot was sun dried uniformly, weighed and expressed in kg/ha.

3.13. Economic analysis

Yield (grain yield + straw yield) from each plot was recorded separately and computed to Indian rupees. The cost of each treatment was also worked out. The cost of cultivation of various treatments was also calculated.

B: C Ratio was worked out using the formula,

$$\text{B: C} = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

B: C ratio of the various treatments were compared with each other.

3.14. Statistical analysis

ANOVA were performed on the data collected in various experiments using the statistical package MSTAT (Freed, 1986) and multiple comparisons among treatment means was done using DMRT.

Results

4. RESULTS

4.1. Survey on the occurrence of sheath blight disease in rice growing locations in Thrissur district of Kerala

Survey was conducted in ten rice growing locations of Thrissur district of Kerala *viz.,* Mannuthy, Chirakekode, Ollukkara, Vellanikkara, Pattikkad, Madakathara, Chalakudy, Adat, Pudurkara and Irinjalakuda during August-September 2013 to study the occurrence of sheath blight. The results are presented in Table 1. Per cent Disease Incidence (PDI) and Per cent Disease Severity (PDS) of sheath blight in the ten rice growing locations ranged from 24.53-51.95 and 44.76-85.53 respectively. The maximum PDI was recorded in paddy fields of Adat (51.95) followed by Irinjalakuda (49.18), Pudurkara (48.10), Chalakudy (48.10), Vellanikkara (46.83) and Madakathara (46.55) and were on par with each other. Pattikkad, Mannuthy and Chirakekode were ranked next and were on par as evidenced by the PDI of 37.40, 34.83 and 32.51 respectively. Of the ten locations surveyed, paddy fields of Ollukkara recorded the least PDI of 24.53. The PDS was also found to be maximum in paddy fields of Adat (85.53) and Chalakudy (84.30) followed by Pudurkara (81.76), Iranjalakuda (78.93) and Mannuthy (73.31) and were on par with each other. Chirakekode (64.30), Pattikkad (56.65), Ollukkara (53.03) and Vellanikkara (50.50 were ranked next as evidenced by the PDS. Of the ten locations surveyed, paddy fields of Madakathara recorded the least PDS of 44.76.

4.2. Collection, isolation and naming of different isolates of *R. solani*

The growth of the fungus developed on PDA medium was purified by repeated sub culturing on the same medium and the pure cultures were maintained. Based on the mycological characters, the pathogen was identified as *Rhizoctonia solani*. The pathogen was fast growing with light brown coloured colonies on PDA medium. Mycelium was hyaline when young and become yellowish brown when old

Table 1. Occurrence of sheath blight in rice growing locations of Thrissur district, Kerala

Sl No.	Place	Variety	Stage of the crop	PDI	PDS
1	Mannuthy	Jyothi	Late tillering stage	34.83^{cd}	73.31 ^{abc}
2	Chirkekode	Uma	Flowering stage	32.51^{cd}	64.30 ^{abcd}
3	Ollukkara	Jyothi	Late tillering stage	24.53 ^{d}	53.03 ^{cd}
4	Vellanikkara	Uma	Flowering stage	46.83 ^{ab}	50.50 ^{cd}
5	Pattikkad	Uma	Flowering stage	37.40 ^{bc}	56.65^{bcd}
6	Madakathara	Jyothi	Active tillering stage	46.55 ^{ab}	44.76 ^{d}
7	Chalakudy	Uma	Flowering stage	48.10 ^{ab}	84.30 ^{a}
8	Adat	Jyothi	Active tillering stage	51.95 ^{a}	85.53 ^{a}
9	Pudurkara	Jyothi	Active tillering stage	48.10 ^{ab}	81.76 ^{a}
10	Irinjalakuda	Jyothi	Flowering stage	49.18 ^{a}	78.93 ^{ab}

Values under same subscript form a homogenous sub group

with frequent septations. Branching of hyphae was occurred at right angles near the distal end of septum and constriction at the point of union with main hyphae, which were the characteristic features of the fungus. Sclerotia were superficial, more or less globose, but flattened below, with indefinite shape. Colour of sclerotia was white when young, becoming brown or dark brown when matured. Individual sclerotia measured up to five mm, but united to form a larger mass in culture.

A total of ten isolates of *R. solani* were obtained from ten locations of Thrissur district. The details of the isolates are presented in Table 2 and these ten isolates were selected for further studies.

4.3. Pathogenicity test

Pathogenicity of ten isolates of *R. solani* was proved by inoculation under *in vivo* condition on rice plants of a highly susceptible variety, Jyothi (PTB-39) at the maximum tillering stage. The actively growing culture of *R. solani* was inoculated by placing in between sheath and culm of the rice plant and was covered with polythene cover after sprinkling water inside to create humidity for development of the disease and the plants were incubated at room temperature (26±2°C). Initial symptoms as small water soaked spots were observed on all isolates on the third day of inoculation. Characteristic symptoms *viz*., circular to ovoid, irregular, water soaked larger lesions developed within seven to ten days by all isolates. The pathogens were reisolated and compared with the original culture of *R. solani.*

4.4. Symptomatology

4.4.1. Symptomatology under natural conditions

During the survey, symptoms were observed on plants in main field at late tillering stage. It appeared initially as greenish grey, ellipsoid or ovoid, water soaked

Table 2. Collection and naming of different isolates of *R. solani* from Thrissur district

SI. NO	Isolate number	Place of collection	Variety
1	ShMTY1	Mannuthy	Jyothi
2	ShCKD2	Chirakekode	Uma
3	ShOKRA3	Ollukkara	Jyothi
4	ShVKA4	Vellanikkara	Uma
5	ShPKD5	Pattikkad	Uma
6	ShMDTA6	Madakathara	Jyothi
7	ShCKDY7	Chalakudy	Uma
8	ShADT8	Adat	Jyothi
9	ShPTKA9	Pudurkara	Jyothi
10	ShIRJK10	Irinjalakuda	Jyothi

Plate 1 (a). Symptoms of sheath blight in different locations

Mannuthy

Chirakekode

Ollukkara

Vellanikkara

Pattikkad

Madakathara

Plate 1 (b). Symptoms of sheath blight in different locations

Chalakudy

Adat

Pudurkara

Irinjalakuda

irregular lesions of one to three cm long. Centre of the spots were greyish white with brown margins. The symptoms started near the water line and spread upwards. Four to five such lesions coalesced and girdled the whole sheath. Sclerotia were formed on or near these lesions and were detached early. Irregular greenish grey lesions with brown margins were also observed on leaf lamina. Under favourable conditions, the disease spread very fast to adjacent tillers and caused death of whole plant (Plate 1 and 2).

4.4.2. Symptomatology under artificial conditions

To study the sheath blight symptom under artificial conditions, 45 days old Jyothi (PTB-39) rice plants were inoculated separately with ten isolates of *R. solani* obtained from ten locations. All the isolates showed small, water soaked greenish grey lesions within third day of inoculation. Later these lesions enlarged as ellipsoid to ovoid, irregularly elongated lesions with pale, greenish grey to greyish white centre narrow dark brown margins within seven to ten days by all the ten isolates. The lesions were present on leaf sheaths and on leaf blades. Finally four to five such lesions coalesced and girdled the whole leaf sheath and culm (Plate 3).

4.5. Characterization of different isolates of *R. solani*

The mycelial characters *viz.,* colour, texture and type of mycelia, sclerotial characters *viz.,* initiation and maturation of sclerotia, number of sclerotia per plate at 10, 15 and 20 Days After Incubation (DAI), weight of 50 sclerotia, sclerotial distribution and exudation rate of sclerotia were studied on four different media *viz.,* Potato Dextrose Agar (PDA) medium, Rose Bengal Agar (RBA) medium, Czapek's Dox Agar (CDA) medium and Richard's medium (RA).

Plate 2. Symptomatology of sheath blight under natural conditions

Symptoms on sheath

Symptoms on leaves

Symptoms on basal portion near water line

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Plate 3. Symptomatology of sheath blight under artificial conditions

Artificial inoculation

symptoms on sheath

Typical symptoms on sheath

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Growth rate of the ten isolates was also studied at 24 h interval on Petri plates mediated with PDA till the pathogen attained full growth. The results of the experiment are presented in Tables 3 to10 and Plate 4.

4.5.1. Cultural and morphological characters of *R. solani* on Potato Dextrose Agar (PDA) medium.

Among the ten isolates of *R. solani*, nine isolates produced light brown colonies on PDA except ShVKA4, where it produced whitish brown colonies (Table 3). Rough textured mycelial growth was observed in four isolates *viz.,* Sh MTY1, Sh OKRA3, Sh PKD5, and Sh PTKA9 whereas six isolates namely Sh CKD2, Sh VKA4, Sh MDTA6, Sh CKDY7, Sh ADT8 and Sh IRJK10 were smooth textured. Fluffy type mycelial growth was observed in five isolates. The remaining five isolates exhibited compact type of mycelium. The production of sclerotia by the ten isolates at 10, 15 and 20 days after inoculation (DAI) revealed that there was a gradual increase in the number of sclerotia in all the isolates at 10, 15 and 20 DAI. At ten DAI, the sclerotial population ranged from 24 to 31 per plate, whereas at 15 DAI, it was 30 to 37 per plate and it reached a level of 40-49 at 20 DAI. The number of days required for the initiation of sclerotia in the culture of each isolate showed variation. It ranged from five to seven days. Variation in the number of days required for the maturation of sclerotia in each culture was recorded and it ranged from six to nine days. The isolate Sh IRJK10 recorded the maximum weight of sclerotia (364 mg) whereas the isolate Sh OKRA3 recorded the minimum weight (190 mg) for 50 sclerotia. Studies on the distribution of sclerotia on PDA medium revealed that, five isolates namely Sh MTY1, Sh CKD2, Sh CKDY7, Sh IRJK10 and Sh ADT8 showed a scattered pattern over the media, whereas the sclerotia of four isolates *viz.,* Sh OKRA3, Sh VKA4, Sh PKD5 and Sh MDTA6 were found distributed at the periphery of the Petri plates. The remaining isolate Sh PTKA9 was found distributed both in the centre and at the

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Table 3. Cultural and morphological characters of different isolates of *R. solani* on Potato Dextrose Agar (PDA) medium

SI.No	Isolates	Colony characters*			Sclerotial characters*							
		Colour of mycelium	Texture	Mycelial type	Sclerotial initiation	Sclerotial maturation	No of sclerotia per plate			Weight of 50 sclerotia (mg)	Distribution of sclerotia	Production of exudates
					DAI	DAI	DAI*					
							10	15	20			
1	Sh MTY1	Light brown	Rough	Compact	5	8	25	35	41	220	Scattered	++
2	Sh CKD2	Light brown	Smooth	Fluffy	5	7	26	34	40	300	Scattered	++
3	Sh OKRA3	Light brown	Rough	Fluffy	5	7	30	37	45	190	Periphery	+++
4	Sh VKA4	Whitish brown	Smooth	Fluffy	5	9	31	36	42	210	Periphery	++
5	Sh PKD5	Light brown	Rough	Fluffy	5	6	24	33	44	280	Periphery	++
6	Sh MDTA6	Light brown	Smooth	Compact	5	8	24	30	49	220	Periphery	+++
7	Sh CKDY7	Light	Smooth	Compact	5	7	24	32	47	240	Scattered	++
8	Sh ADT 8	Light	Smooth	Compact	6	8	28	35	41	280	Scattered	++
9	Sh PTKA9	Light brown	Rough	Fluffy	5	8	24	36	45	281	Centre&Periphery	+++
10	Sh IRJK10	Light brown	Smooth	compact	5	7	28	34	47	364	Scattered	++

*Mean of three replications DAI- Days after Incubation ++++-very high +++-high ++-medium +-low

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Table 4. Growth rate of different isolates of *R.solani* on Potato Dextrose Agar medium

SI.No	Isolates	Colony diameter* (cm)		
		Days After Incubation (DAI)		
		1	2	3
1	Sh MTY1	2.3	7.5	9
2	Sh CKD2	4.3	8.3	9
3	Sh OKRA3	3.6	8.5	9
4	Sh VKA4	4.6	8.7	9
5	Sh PKD5	4.6	8.5	9
6	Sh MDTA6	4.9	8.7	9
7	Sh CKDY7	5.7	8.5	9
8	Sh ADT8	3.3	8.6	9
9	Sh PTKA9	3.2	8.5	9
10	Sh IRJK10	2.9	8.7	9

*Mean of three replications

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periphery of the medium. The production of sclerotial exudation was medium to high in all the isolates (Plate 5).

To study the growth rate of ten isolates, each isolate was inoculated at the centre of the PDA medium and diameter of colony was measured at 24 h interval till it completely covered the Petri plate. The results are presented in Table 4. On the first day of inoculation, the isolates *viz.,* Sh VKA4, Sh PKD 5, Sh MDTA 6 and Sh CKDY7 spread to more than half of the Petri plate (4.6-5.7cm). By the second day, nine isolates spread to the diameter of 8.3 to 8.7cm, whereas the isolate Sh MTY1 spread up to 7.6cm. All the ten isolates fully covered the Petri plate (9cm) on the third day after inoculation.

4.5.2. Cultural and morphological characters of *R. solani* on Rose Bengal Agar (RBA) medium.

All the ten isolates of *R. solani* produced whitish brown colonies (Table 5). A smooth textured mycelial growth was observed in all the isolates of *R. solani*. Compact type of mycelial growth was observed in all the ten isolates. There was a gradual increase in the number of sclerotia produced in all isolates at 10, 15 and 20 DAI. At ten DAI, the sclerotial population ranged from 17 to 25 per plate, whereas at 15 DAI, it was 24-32 per plate and it reached a level of 32 to 40 at 20 DAI. The number of days required for the initiation of sclerotia in the culture of each isolate showed variation. It ranged from five to six days. Variation in the number of days required for the maturation of sclerotia in each culture was recorded and it ranged from seven to nine days. The isolate Sh CKD2 recorded the maximum weight of sclerotia (310 mg) whereas the isolate Sh CKDY7 recorded the minimum weight (190 mg) for 50 sclerotia. Studies on the distribution of sclerotia on RBA medium revealed that, six isolates namely Sh MTY1, Sh OKRA3, Sh PKD5, Sh MDTA6, Sh CKDY7 and Sh PTKA9 was distributed at centre over the RBA medium, whereas the

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Table 5. Cultural and morphological characters of different isolates of *R. solani* on Rose Bengal Agar (RBA) medium

SI.No	Isolates	Colony characters*			Sclerotial characters*							
		Colour of mycelium	Texture	Mycelial type	Sclerotial initiation	Sclerotial maturation	No of sclerotia per plate			Weight of 50 sclerotia (mg)	Distribution of sclerotia	Production of exudates
					DAI	DAI	DAI*					
							10	15	20			
1	Sh MTY1	Whitish brown	Smooth	Compact	6	8	18	25	32	270	Centre	++
2	Sh CKD2	Whitish	Smooth	Compact	5	7	21	27	35	310	Centre&Periphery	++
3	Sh OKRA3	Whitish brown	Smooth	Compact	5	8	17	28	34	240	Centre	+++
4	Sh VKA4	Whitish brown	Smooth	Compact	6	8	24	29	33	260	Scattered	++
5	Sh PKD5	Whitish brown	Smooth	Compact	5	7	23	31	39	230	Centre	++
6	Sh MDTA6	Whitish	Smooth	Compact	6	8	19	24	37	270	Centre	+++
7	Sh CKDY 7	Whitish brown	Smooth	Compact	5	8	22	30	38	190	Centre	++
8	Sh ADT8	Whitish	Smooth	Compact	6	8	25	32	40	230	Scattered	++
9	Sh PTKA9	Whitish brown	Smooth	Compact	6	9	22	28	38	271	Centre	+++
10	Sh IRJK10	Whitish brown	Smooth	Compact	6	8	24	24	34	227	Scattered	++

*Mean of 3 Replications DAI- Days after Incubation ++++-very high +++-high ++-medium +-low

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Table 6. Growth rate of different isolates of *R.solani* on Rose Bengal Agar medium

SI.No	Isolates	Colony diameter* (cm)			
		Days After Incubation (DAI)			
		1	2	3	4
1	Sh MTY1	4.3	6.6	8.2	9
2	Sh CKD2	4.1	6.1	8.4	9
3	Sh OKRA3	4.1	6.3	8.2	9
4	Sh VKA4	4.1	6.4	8.2	9
5	Sh PKD5	4.5	6.4	8.2	9
6	Sh MDTA6	3.9	6.4	8.1	9
7	Sh CKDY7	4.0	6.3	8.2	9
8	Sh ADT8	3.7	6.4	8.1	9
9	Sh PTKA9	4.0	6.2	8.0	9
10	Sh IRJK10	4.3	6.4	8.6	9

*Mean of three replications

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sclerotia of isolates Sh VKA4, Sh ADT8 and Sh IRJK10 showed a scattered pattern over the medium. The isolate Sh CKD2 was found distributed both in the centre and at the periphery of the medium. The production of sclerotial exudation was medium to high in all isolates.

To study the growth rate of ten isolates on RBA medium, each isolate was inoculated at the centre of the plate containing the medium. The diameter of colony was measured at 24 h interval till it completely covered the Petri plate. The results are presented in Table 6. On the first day of inoculation, the isolates namely Sh VKA4, Sh PKD5 and Sh MDTA6 spread to 4.2 to 4.9 cm. By the second day, ten isolates spread the half of the Petri plate 6.1 to 6.6 cm. By the third day, all ten isolates spread up to 8.0 to 8.6. On fourth day of inoculation, all the ten isolates fully covered the Petri plate (9 cm).

4.5.3. Cultural and morphological characters of *R. solani* on Czapek's Dox Agar (CDA) medium.

The data given in Table 7 showed that all the isolates of *R. solani* produced whitish brown coloured colonies in CDA medium. A rough textured mycelial growth was observed in nine isolates of *R. solani* except isolate Sh VKA4, where it produced smooth textured colonies. Fluffy type mycelial growth was observed in five isolates namely Sh MTY1, Sh OKRA3, Sh VKA4, Sh CKDY7 and Sh ADT8. The remaining five isolates *viz.,* Sh CKD2, Sh PKD5, Sh MDTA6, Sh PTKA9 and Sh IRJK10 exhibited compact type of mycelium. The production of sclerotia by the ten isolates at 10, 15 and 20 DAI revealed that, there was a gradual increase in the number of sclerotia in isolates at 10, 15 and 20 DAI. At ten DAI, the sclerotial population ranged from 8 to 17 per plate, whereas at 15 DAI, it was 13 to 22 per plate and it reached a level of 19 to 27 at 20 DAI. The number of days required for the initiation of sclerotia in the culture of each isolate showed variation. It ranged from five to

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Table 7. Cultural and morphological characters of different isolates of *R. solani* on Czapek's (Dox) Agar (CDA) medium

SI.No	Isolates	Colony characters*			Sclerotial characters*							
		Colour of mycelium	Texture	Mycelial type	Sclerotial initiation	Sclerotial maturation	No of sclerotia per plate			Weight of 50 sclerotia (mg))	Distribution of sclerotia	Production of exudates
					DAI	DAI	DAI*					
							10	15	20			
1	Sh MTY1	Whitish brown	Rough	Fluffy	7	9	11	17	23	320	Centre	++
2	Sh CKD2	Whitish brown	Rough	Compact	7	9	8	13	25	260	Scattered	+++
3	Sh OKRA3	Whitish brown	Rough	Fluffy	7	9	14	19	22	290	Centre	++
4	Sh VKA4	Whitish brown	Smooth	Fluffy	7	9	16	21	22	160	Scattered	++
5	Sh PKD5	Whitish	Rough	Compact	7	9	10	16	21	280	Scattered	+++
6	Sh MDTA6	Whitish	Rough	Compact	7	9	9	14	19	220	Centre&Periphery	++
7	Sh CKDY7	Whitish brown	Rough	Fluffy	5	9	13	19	27	240	Scattered	++
8	Sh ADT8	Whitish brown	Rough	Fluffy	7	9	17	22	26	280	Centre&Periphery	++
9	Sh PTKA9	Whitish brown	Rough	Compact	5	7	8	17	21	231	Centre&Periphery	+++
10	Sh IRJK10	Whitish brown	Rough	Compact	5	7	13	20	23	264	Scattered	++

* Mean of three replications DAI- Days after Incubation ++++-very high +++-high ++-medium +-low

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Table 8. Growth rate of different isolates of *R.solani* on Czapek's (Dox) Agar medium

SI.No	Isolates	Colony diameter* (cm)				
		Days After Incubation (DAI)				
		1	2	3	4	5
1	Sh MTY1	2.5	4.8	6.5	7.7	9
2	Sh CKD2	2.3	4.5	6.4	7.6	9
3	Sh OKRA3	2.5	4.5	6.4	7.8	9
4	Sh VKA4	2.4	4.8	6.3	7.7	9
5	Sh PKD5	2.5	4.6	6.5	7.7	9
6	Sh MDTA6	2.5	4.5	6.3	7.5	9
7	Sh CKDY7	2.4	4.5	6.6	7.5	9
8	Sh ADT8	2.4	4.3	6.3	7.6	9
9	Sh PTKA9	2.5	4.5	6.4	7.7	9
10	Sh IRJK10	2.3	4.5	6.5	7.8	9

*Mean of three replications

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seven days. Variation in number of days required for the maturation of sclerotia in each culture was recorded and it ranged from seven to nine days. The isolate Sh MTY1 recorded the maximum weight of sclerotia (320 mg) whereas the isolate Sh VKA4 recorded the minimum weight (160 mg) for 50 sclerotia. Studies on the distribution of sclerotia on Czapek's medium revealed that, two isolates namely Sh MTY1 and Sh OKRA3 were distributed at centre over the medium, whereas the sclerotia of isolates Sh CKD2, Sh VKA4, Sh PKD5, Sh CKDY7 and Sh IRJK10 showed scattered pattern over the medium. The isolates Sh MDTA6, Sh ADT8 and Sh PTKA9 were found distributed both in the centre and at the periphery of the medium. The production of sclerotial exudation was medium to high in all isolates.

To study the growth rate of ten isolates, each isolate was inoculated at the centre of the Czapek's medium and diameter of colony was measured at 24 h interval till it completely covered the Petri plate. The results are presented in Table 8. On the first day of inoculation, all the ten isolates spread (2.3 to 2.5cm). By the second day, ten isolates spread the half of the petri plate 4.5 to 4.8 cm. By the third day, all ten isolates spread more than half of the petri plate 6.3 to 6.6 cm. By the fourth day, all the isolates spread up to diameter of 7.5 to 7.8cm. All the ten isolates fully covered the Petri plate (9 cm) on fifth day after inoculation.

4.5.3. Cultural and morphological characters of *R. solani* on Richard's Agar (RA) medium.

All the ten isolates produced whitish brown coloured colonies (Table 9). A smooth textured mycelial growth was observed in seven isolates namely Sh MTY1, Sh CKD2, Sh OKRA3, Sh VKA4, Sh MDTA6, Sh CKDY7 and Sh ADT8. Whereas the isolates namely Sh PKD5, Sh PTKA9 and Sh IRJK10 showed rough textured colonies. Compact type of mycelial growth was observed in all the ten isolates. The production of sclerotia by the ten isolates at 10, 15 and 20 DAI revealed that, there

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Table 9. Cultural and morphological characters of different isolates of *R. solani* on Richards's Agar (RA) medium

SI.No	Isolates	Colony characters*			Sclerotial characters*							
		Colour of mycelium	Texture	Mycelial type	Sclerotial initiation	Sclerotial maturation	No of sclerotia per plate			Weight of 50 sclerotia (mg)	Distribution of sclerotia	Production of exudates
					DAI	DAI	DAI*					
							10	15	20			
1	Sh MTY1	Whitish brown	Smooth	Compact	7	8	12	18	22	220	Scattered	++
2	Sh CKD2	Whitish brown	Smooth	Compact	7	9	10	14	21	210	Centre	++
3	Sh OKRA3	Whitish brown	Smooth	Compact	7	9	12	15	20	260	Centre	++
4	Sh VKA4	Whitish	Smooth	Compact	7	9	11	19	23	310	Scattered	++
5	Sh PKD5	Whitish	Rough	Compact	7	9	10	20	24	230	Centre	++
6	Sh MDTA6	Whitish	Smooth	Compact	9	10	10	14	19	270	Scattered	++
7	Sh CKDY7	Whitish brown	Smooth	Compact	7	9	14	17	25	290	Periphery	++
8	Sh ADT8	Whitish brown	Smooth	Compact	9	10	15	18	24	180	Centre	++
9	Sh PTKA9	Whitish brown	Rough	Compact	9	10	12	17	23	281	Centre	++
10	Sh IRJK10	Whitish brown	Rough	Compact	7	9	14	19	24	262	Periphery	++

* Mean of three replications DAI- Days after Incubation ++++-very high +++-high ++-medium

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Table 10. Growth rate of different isolates of *R.solani* on Richard's Agar medium

SI.No	Isolate	Colony diameter* (cm)				
		Days after incubation				
		1	**2**	**3**	**4**	**5**
1	Sh MTY1	2.2	3.5	5.5	7.9	9
2	Sh CKD2	2.1	3.1	5.5	8.6	9
3	Sh OKRA3	2.1	3.1	5.5	8.8	9
4	Sh VKA4	2.0	3.0	5.4	7.7	9
5	Sh PKD5	2.1	2.9	5.7	7.7	9
6	Sh MDTA6	2.2	3.0	5.6	7.5	9
7	Sh CKDY7	2.3	3.0	5.7	8.8	9
8	Sh ADT8	2.2	3.1	5.5	8.4	9
9	Sh PTKA9	2.1	2.8	5.6	8.5	9
10	Sh IRJK10	2.0	3.0	5.8	8.6	9

*Mean of three replications

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was a gradual increase in the number of sclerotia in isolates at 10, 15 and 20 DAI. At ten DAI, the sclerotial population ranged from 10 to 15 per plate, whereas at 15 DAI, it was 14 to 20 per plate and it reached a level of 19 to 25 at 20 DAI. The number of days required for the initiation of sclerotia in the culture of each isolate showed variation. It ranged from seven to nine days. Variation in number of days required for the maturation of sclerotia in each culture was recorded and it ranged from eight to ten days. The isolate Sh VKA4 recorded the maximum weight of sclerotia (310 mg) whereas the isolate Sh ADT8 recorded the minimum weight (180 mg) for 50 sclerotia. Studies on the distribution of sclerotia on RA medium revealed that, three isolates namely Sh MTY1, Sh VKA4 and Sh MDTA6 showed scattered pattern over the medium, whereas the sclerotia of isolates *viz.,* Sh CKD2, Sh OKRA3, Sh PKD5, Sh ADT8 and Sh PTKA9 were distributed at the centre of the medium. The remaining two isolates namely Sh CKDY7and Sh IRJK10 were found distributed at the periphery of the medium. The production of sclerotial exudation was medium to high in all isolates.

To study the growth rate of ten isolates on RA medium, each isolate was inoculated at the centre of the plate containing the medium. The diameter of the colony was measured at 24 h interval till it completely covered the Petri plate. The results are presented in Table 10. On the first day of inoculation, all the ten isolates spread (2.0 to 2.3 cm). By the second day, ten isolates spread the diameter of 2.8 to 3.5cm. By the third day, all ten isolates covered more than half of the Petri plate 5.4 to 5.8cm. By the fourth day all the isolates spread up to diameter of 7.7 to 8.8cm. By the fifth day of incubation, all ten isolates fully covered the Petri plate.

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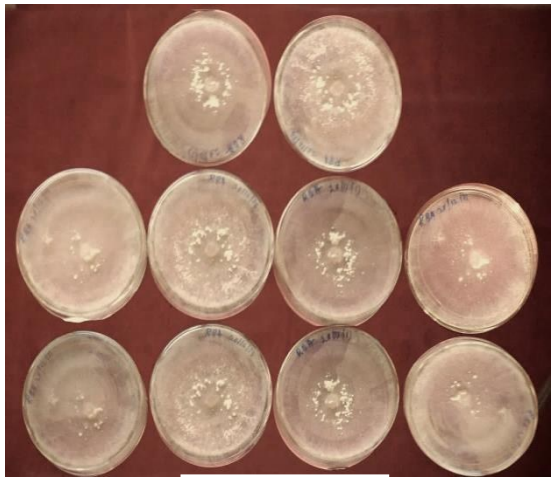
Plate 4. Growth of *R. solani* on different media

PDA



RBA

CDA

Richard's Agar

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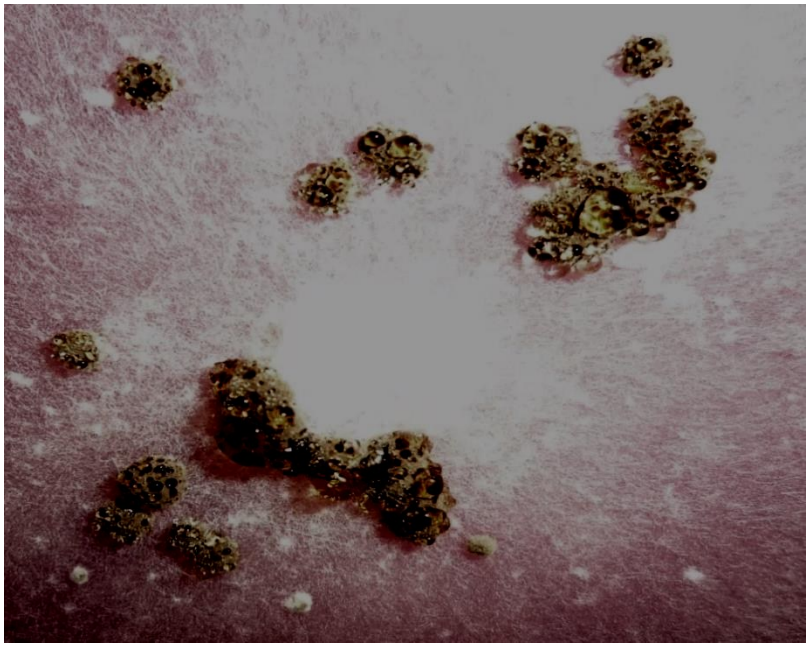
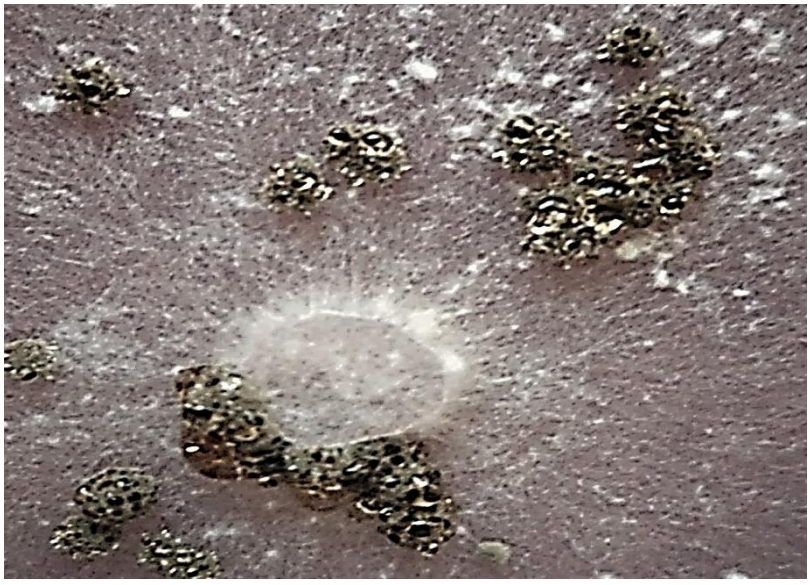
Plate 5. Production of sclerotial exudation





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4.5.4. Cluster analysis of *R.solani* isolates based on cultural and morphological characters

Similarity index of ten isolates of *R. solani* were computed based on cultural and morphological characters, by using NTSYS pc 2.02 Software. The results are presented in Table 11 and Fig 1. The dendrogram was constructed by using Unweighed Pair Group Average Method (UPGMA) as shown in Fig.5. The lowest similarity index of 0.4444 was observed in the isolate ShMDTA6 followed by 0.5556 between isolate ShCKDY7 and ShCKD2. The highest similarity index of 0.8889 was observed between isolate ShADT8 and ShVKA4 followed by 0.7778 between isolates ShVKA4 and ShOKRA3. The isolates were grouped into two clusters A and B based on cultural characters (Table 12). In cluster A, highest similarity coefficient of 0.69 was recorded between isolates ShMTY1, ShADT8 and ShOKRA3 (Fig. 1) Cluster A was further divided in to two sub clusters A1 and A2. In sub cluster A1, the highest similarity coefficient of 0.78 was recorded between isolates ShMTY1, ShADT8, ShOKRA3, ShIRJK10 and ShPTKA9, whereas lowest similarity index of 0.75 was recorded between isolates ShCKD2, ShVKA4 and ShPKD5 in sub cluster A2. Cluster B had no sub clusters and it showed the similarity index of 0.67 between the isolate of ShCKD2 and ShCKDY7.

4.6. Studies on the microbial profile of liquid organic formulations *viz.*, Panchagavya, Dasagavya and Jeevamrutha

Microorganisms *viz.,* fungi, bacteria, actinomycetes and *Pseudomonas* spp. were enumerated from the three liquid organic formulations *viz.,* Panchagavya, Dasagavya and Jeevamrutha at 25, 45, 90, 120 and 210 days intervals by serial dilution plate technique. The results are presented in Tables 13 to 15.

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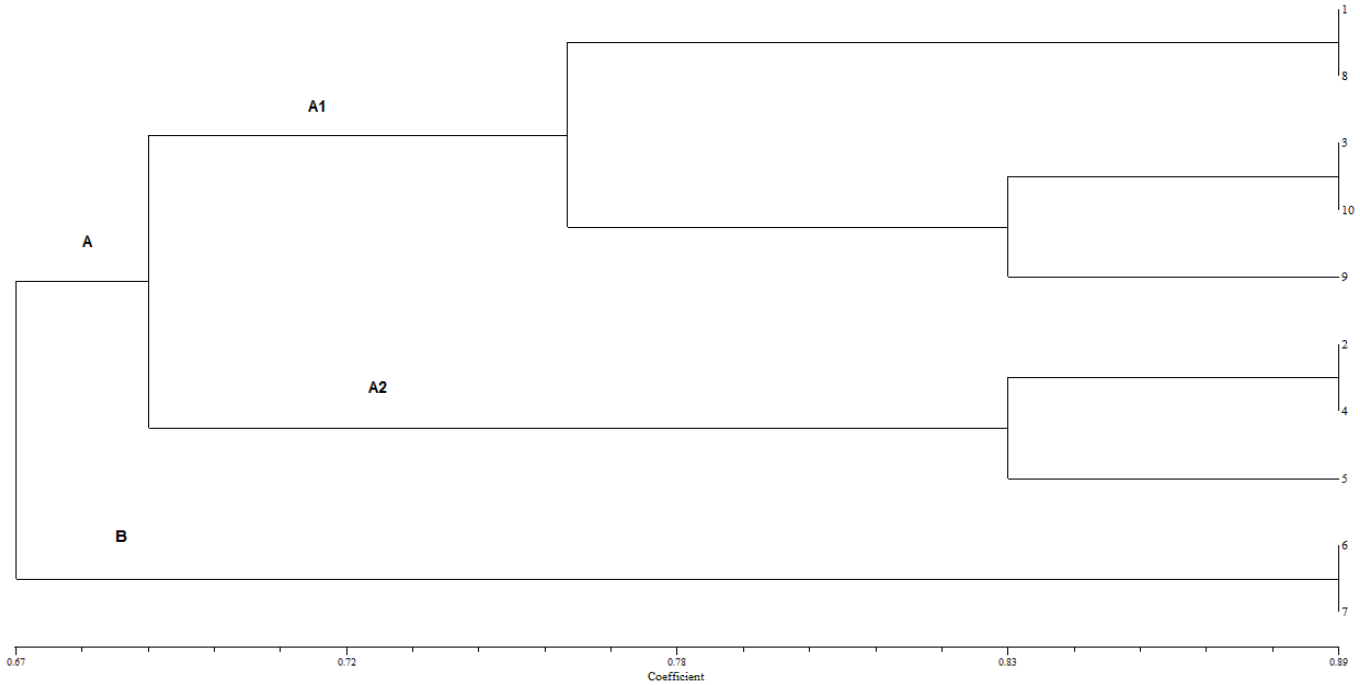

1. **ShMTY1**
2. **ShCKD2**
3. **ShOKRA3**
4. **ShVKA4**
5. **Sh PKD5**
6. **ShMDTA6**
7. **ShCKDY7**
8. **ShADT8**
9. **ShPTKA9**
10. **ShIRJK10**

Fig 1. Unweighed Pair Group Average Method (UPGMA) Dendrogram based on cultural and morphological characters of various isolates of *R.solani*

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Table 11. Similarity matrix of *R. solani* isolates based on cultural and morphological characters

Isolates	ShMTY1	ShCKD2	ShOKRA3	ShVKA4	ShPKD5	ShMDTA6	ShCKDY7	Sh ADT8	ShPTKA9	ShIRJK10
Sh MTY1	1.0000									
Sh CKD2	0.6667	1.0000								
Sh OKRA3	0.7778	0.6667	1.0000							
Sh VKA4	0.7778	0.8889	0.7778	1.0000						
Sh PKD5	0.5556	0.8889	0.5556	0.7778	1.0000					
Sh MDTA6	0.4444	0.5556	0.6667	0.6667	0.6667	1.0000				
Sh CKDY7	0.5556	0.6667	0.7778	0.7778	0.7778	0.8889	1.0000			
Sh ADT8	0.8889	0.7778	0.8889	0.8889	0.6667	0.5556	0.6667	1.0000		
Sh PTKA9	0.6667	0.5556	0.8889	0.6667	0.6667	0.7778	0.8889	0.7778	1.0000	
Sh IRJK10	0.6667	0.7778	0.8889	0.6667	0.6667	0.5556	0.6667	0.7778	0.7778	1.0000

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Table 12. Grouping of *R. solani* isolates based on similarity index

Cluster	Sub cluster	Isolates
A	A1	Sh MTY1, Sh ADT8, Sh OKRA3, Sh IRJK10 and Sh PTKA9
	A2	Sh CKD2, Sh VKA4, and Sh PKD5
B		Sh MDTA6 and Sh CKDY7

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Table 13. Microbial load of Panchagavya at different days of storage

Microorganisms	25 DAP	60 DAP	90 DAP	120 DAP	210 DAP
*Fungi ($x10^4$ cfu/ml)	28.0	27.33	24.66	34.0	42.0
*Bacteria($x10^5$ cfu/ml)	97.33	95.0	93.66	90.66	64.0
**Pseudomonas* Spp. ($x10^5$ cfu/ml)	90.66	85.66	79.33	80.33	39.0
*Actinomycetes ($x10^7$ cfu/ml)	0	0	0	0	0

*Mean of 3 replications. DAP- Days after preparation. cfu- colony forming units

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4.6.1. Enumeration of microorganisms from Panchagavya

When the total microbial population from Panchagavya at 25 days was enumerated, the total bacterial population was high 97.33 x 10^5 cfu/ml (Table 13) followed by *Pseudomonas* spp. (90.66 x 10^5 cfu/ml). Compared to bacterial population, fungal population was less (28 x 10^4 cfu/ml). No actinomycetes growth was observed. At 45 DAP, the total bacterial population was constant (95 x10^5 cfu/ml) followed by *Pseudomonas* spp. (85.66 x 10^5 cfu/ml) and fungal population was 27.33x10^{-4} cfu/ml. At 90 DAP, the total number of bacteria was 93.66 x 10^5 cfu/ml, followed by *Pseudomonas* spp. (79.33 x 10^5 cfu/ml) and the number of fungal colonies were 24.66 x 10^4 cfu/ml. At 120 DAP, the total number of bacterial population slightly decreased (90.66 x 10^5 cfu/ml) followed by *Pseudomonas* spp. (80.33 x 10^5 cfu/ml); but the fungal colonies increased to 34 x10^4 cfu/ml. At 210 DAP, the total number of fungal colonies increased (42 x10^4 cfu/ml) and the number of bacterial population decreased to 64x10^5 cfu/ml followed by *Pseudomonas* spp. (39x 10^5 cfu/ml). Actinomycetes colonies were not observed in any of the samples tested.

4.6.2. Enumeration of microorganisms from Dasagavya

When the total microbial population from Dasagavya at 25 days was enumerated, the bacterial population was high (90.33 x 10^5 cfu/ml) followed by *Pseudomonas* spp. 78.66 x 10^5 cfu/ml (Table 14). Compared to bacterial population, fungal colonies were less (27.66 x 10^4 cfu/ml). At 60 DAP, the total bacterial population was constant (89.66 x10^5 cfu/ml) followed by *Pseudomonas* spp. (75.66 x 10^5 cfu/ml) and fungal population (28 x10^4 cfu/ml). At 90 DAP, the number of bacterial colonies were 88 x 10^5 cfu/ml, followed by *Pseudomonas* spp. (73 x 10^5 cfu/ml). The number of fungal colonies were 27 x 10^4 cfu/ml. At 120 DAP, total bacterial population slightly decreased (86.66 x 10^5 cfu/ml) followed by

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Table 14. Microbial load of Dasagavya at different days of storage

Microorganisms	25 DAP	60 DAP	90 DAP	120 DAP	210 DAP
*Fungi ($x10^4$ cfu/ml)	27.66	28.0	27.0	30.0	48.0
*Bacteria ($x10^5$ cfu/ml)	90.33	89.66	88.0	86.66	67.0
**Pseudomonas* Spp. ($x10^5$ cfu/ml)	78.66	75.66	73.0	69.0	41.0
*Actinomycetes ($x10^7$ cfu/ml)	0	0	0	0	0

*Mean of 3 replications. DAP- Days after preparation. cfu- colony forming units

Table 15. Microbial load of Jeevamrutha at different days of storage

Microorganisms	25 DAP	60 DAP	90 DAP	120 DAP	210 DAP
*Fungi ($x10^4$ cfu/ml)	28.0	26.0	24.0	33.0	39.0
*Bacteria ($x10^5$ cfu/ml)	87.0	89.66	84.0	82.0	64.0
**Pseudomonas* Spp. ($x10^5$ cfu/ml)	80.33	82.33	76.0	58.0	52.0
*Actinomycetes ($x10^7$ cfu/ml)	0	0	0	0	0

*Mean of 3 replications. DAP- Days after preparation. cfu- colony forming units

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Pseudomonas spp. (69 x 10^5 cfu/ml), but the fungal colonies increased (30 x10^4 cfu/ml). At 210 DAP, total number of fungal colonies increased (48 x10^4 cfu/ml) and the total number of bacterial population decreased (67x10^5 cfu/ml), followed by *Pseudomonas* spp. (41x 10^5 cfu/ml). Actinomycetes colonies were not found in any of the samples tested.

4.6.3. Enumeration of microorganisms from Jeevamrutha

When the total microbial population from Jeevamrutha at 25 days was enumerated, the total bacterial population was high (87 x 10^5 cfu/ml), followed by *Pseudomonas* spp. (80.33 x 10^5 cfu/ml) (Table 15). Compared to bacterial population, fungal population was less (28 x 10^4 cfu/ml). At 60 DAP, the total bacterial population was constant (89.66 x10^5 cfu/ml), followed by *Pseudomonas* spp. (82.33 x 10^5 cfu/ml) and fungal population (26 x10^4 cfu/ml). At 90 DAP, the total number of bacteria was 84 x 10^5 cfu/ml, followed by *Pseudomonas* spp. 76 x10^5 cfu/ml and the number of fungal colonies were 24 x 10^4 cfu/ml. At 120 DAP, total bacterial population slightly decreased (82 x 10^5 cfu/ml) followed by *Pseudomonas* spp. (58 x 10^5 cfu/ml) but the fungal colonies increased (33 x 10^4 cfu/ml). At 210 DAP, the total number of fungal colonies increased to 39 x10^4 cfu/ml and the bacterial population decreased to 64x1^{-5} cfu/ml followed by *Pseudomonas* spp. (52 x 10^5 cfu/ml). No actinomycetes colonies were found in any of the samples tested.

4.7. Management of sheath blight of rice

4.7.1. *In vitro* evaluation of liquid organic formulations against different isolates of *R. solani*

In vitro evaluation of various liquid organic formulations *viz*., Panchagavya, at 2 and 3%; Dasagavya at 2 and 3%; Jeevamrutha at 10 and 20% and *P. fluorescens* 2% (Biocontrol check) were carried out against different isolates of *R. solani.* The

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Table 16. *In vitro* evaluation of liquid organic formulations against different isolates of *R. solani*

Per cent Inhibition Over Control (PIOC) (3 DAI)							
Isolates	**Panchagavya 2 %**	**Panchagavya 3 %**	**Dasagavya 2%**	**Dasagavya 3%**	**Jeevamrutha 10%**	**Jeevamrutha 20%**	***P. fluorescens* 2% (Biocontrol check)**
Sh MTY1	69.25^{bc}	76.66	69.63^{bc}	75.55	64.44^{d}	71.85^{c}	80.73^{a}
Sh CKD2	76.29^{a}	78.14	76.66^{a}	78.14	69.62^{abcd}	78.51^{ab}	79.99 ^{a}
Sh OKRA3	73.70^{ab}	77.77	68.51^{bc}	79.25	72.22^{abc}	76.29^{b}	78.51 ^{ab}
Sh VKA4	75.18^{ab}	80.73	72.96^{abc}	79.62	85.18^{a}	79.62^{a}	73.69 ^{bc}
Sh PKD5	65.92^{c}	74.07	67.40^{c}	77.03	68.14^{bcd}	79.25^{ab}	79.99 ^{a}
Sh MDTA6	69.99^{bc}	75.55	74.81^{ab}	77.40	65.55^{d}	67.03^{d}	82.96 ^{a}
Sh CKDY7	75.18^{ab}	77.03	69.25^{bc}	77.03	67.77^{bcd}	67.40^{d}	81.70 ^{a}
Sh ADT 8	65.92^{c}	77.03	74.07^{abc}	73.69	65.55^{d}	67.40^{d}	81.85 ^{a}
Sh PTKA9	73.33^{ab}	74.06	69.63^{bc}	76.66	66.29^{cd}	70.37^{c}	73.70 ^{bc}
Sh IRJK10	70.37^{abc}	77.77	74.07^{abc}	78.51	73.33^{ab}	77.77^{ab}	72.21 ^{c}
CD 5%	5.30	NS	5.92	NS	5.52	2.80	5.77

DAI- Days after Incubation, Values under same subscript form a homogenous sub group

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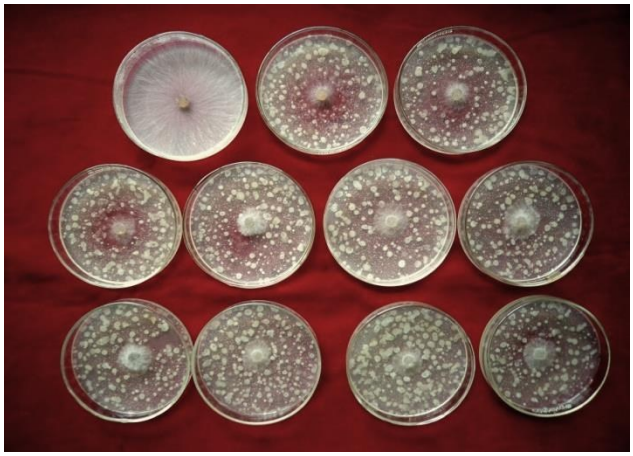
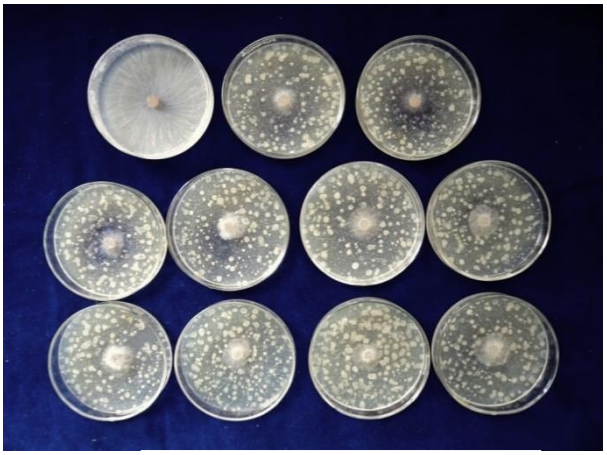
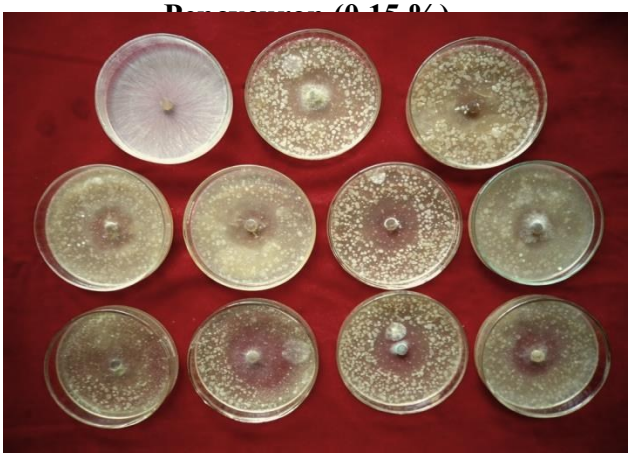
Plate 6. *In vitro* evaluation of liquid organic formulations



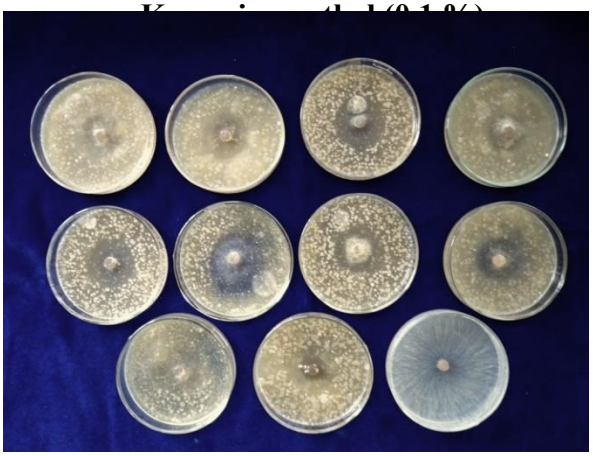
Panchagavya 2%



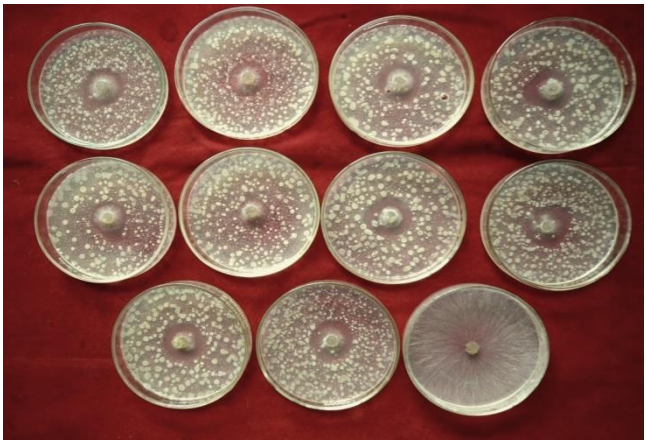
Panchagavya 3%



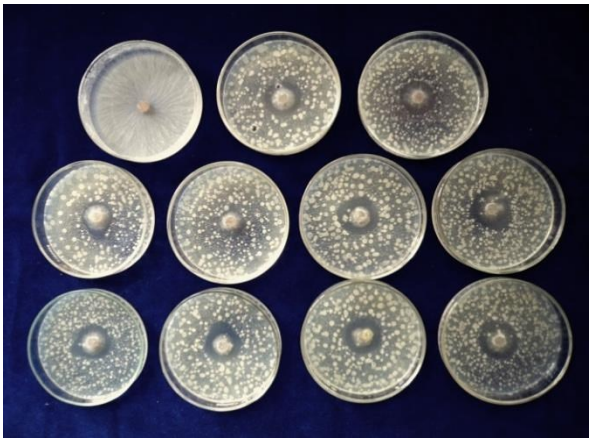
Dasagavya 2%



Dasagavya 3%



Jeevamrutha 10%



Jeevamrutha 20%

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Table 17. *In vitro* evaluation of new generation fungicides against different isolates of *R. solani*

Per cent Inhibition Over Control (PIOC) (3 DAI)					
Isolates	**Kresoxim methyl 44 SC (0.1 %)**	**Pencycuron 25 SC (0.15 %)**	**Flusilazole 40 EC (0.15%)**	**(Iprodione 25 WP + Carbendazim 25**	**Propiconazole 25 EC (Fungicidal check) (0.1 %)**
Sh MTY1	64.44[d]	83.70	100	100	100
Sh CKD2	65.92[cd]	85.80	100	100	100
Sh OKRA3	67.40[bcd]	86.66	100	100	100
Sh VKA4	71.48[ab]	86.66	100	100	100
Sh PKD5	71.48[ab]	85.18	100	100	100
Sh MDTA6	65.55[cd]	82.92	100	100	100
Sh CKDY7	74.44[a]	82.11	100	100	100
Sh ADT 8	72.96[a]	84.59	100	100	100
Sh PTKA9	70.00[abc]	78.22	100	100	100
Sh IRJK10	73.70[a]	80.70	100	100	100
CD 5%	4.187	NS	NS	NS	NS

DAI- Days After Incubation, Values under same subscript form a homogenous sub group

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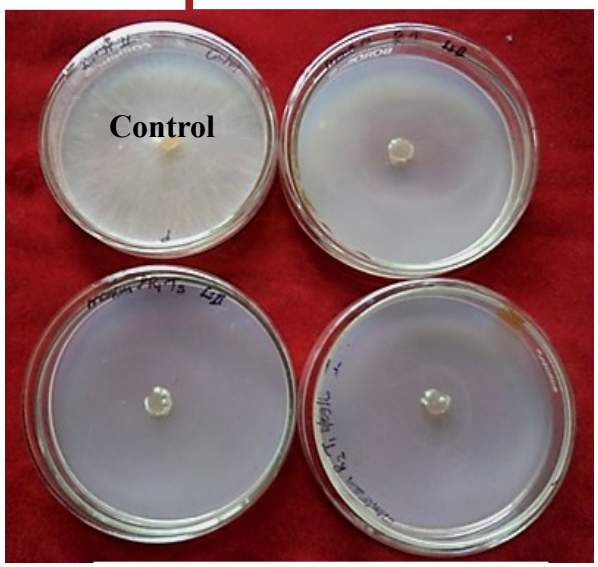
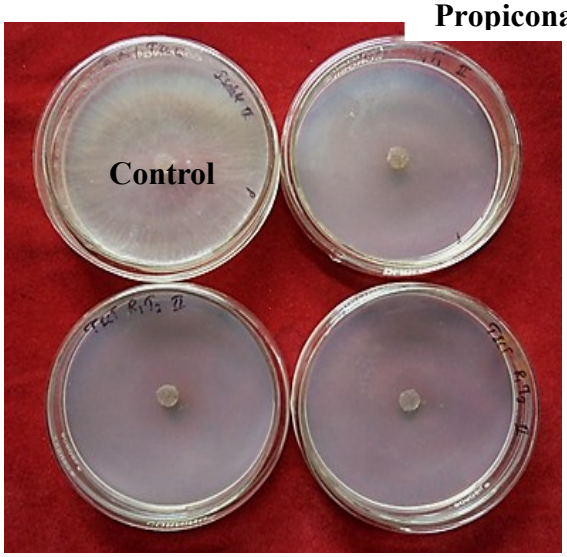
Plate 7. *In vitro* evaluation of different new generation fungicides

(Flusilazole 0.15 %)

Iprodione 25 WP + Carbendazim 25WP (0.15



Propiconazole 25 EC (0.1 %)



Pencycuron (0.15 %)

Kresoxim methyl (0.1 %)

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results are presented in Table 16 and Plate 6. The study revealed that Jeevamrutha at 10 per cent concentration showed maximum inhibition of 85.18 per cent which was on par with Jeevamrutha 20% (79.62). Panchagavya at 3 and 2% ranked next with per cent inhibition of 80.73 and 76.29 respectively. Dasagavya at 3and 2 % were ranked next with per cent inhibition of 79.25 and 76.66 respectively. The standard biocontrol check *P. fluorescens* 2% showed a per cent inhibition of 82.96.

4.7.2. *In vitro* evaluation of new generation fungicides against different isolates of *R. solani*

In vitro evaluation of new generation fungicides *viz*., Kresoxim methyl 44 SC (0.1 %), Pencycuron 25 SC (0.15 %), Flusilazole 40 EC (0.15 %), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) and Propiconazole 25 EC (0.1 %) (Fungicidal check) were carried out against different isolates of *R. solani.* The results are presented in Table 17 and Plate 7. The study revealed that the Flusilazole 40 EC (0.15 %), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) and Propiconazole 25 EC (0.1 %) (Fungicidal check) showed 100 per cent inhibition over control. Pencycuron 25 SC (0.15 %) ranked next with per cent inhibition of 86.66. Kresoxim methyl 44 SC (0.1 %) was with per cent inhibition of 74.44.

4.8. Field experiment for the integrated management of sheath blight of rice

A field experiment was laid out to study the efficacy of selected liquid organic formulations, new generation fungicides and Vermicompost against sheath blight of rice (Plate 8).

Disease reaction was assessed by calculating Per cent Disease Index (PDI) and Percent Disease Severity (PDS) at 75 DAT. Growth parameters *viz.,* plant height, number of productive tillers/m^2 and yield attributes *viz.,* panicles/ hill, number of

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Plate 8. a) Field view of the experiment

b) Fertilizer application

c) Spraying

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Table 18. Evaluation of new generation fungicides, liquid organic formulations, vermicompost and EM for the management of sheath blight of

Treatments		Disease reaction at 75 DAT	
		PDI	PDS
T1	Panchagavya 3% at 45 & 60 DAT	39.63	35.17
T2	Jeevamrutha 20% at 45 & 60 DAT	36.50	38.43
T3	Flusilazole 40 EC (0.15%) at 45 & 60 DAT	11.17	10.53
T4	(Iprodione 25WP + Carbendazim 25WP) (0.15%) at 45 & 60 DAT	10.70	10.93
T5	Vermicompost @ 2.5 t/ha as basal	41.97	40.23
T6	Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP + Carbendazim 25 WP) (0.15%) at 45 & 60 DAT	38.13	27.80
T7	Vermicompost @ 2.5 t/ha as basal +Jeevamrutha 20% at 45 & 60 DAT	41.70	35.20
T8	Vermicompost @ 2.5 t/ha as basal + Flusilazole 40 EC (0.15%) at 45 & 60 DAT	12.80	14.60
T9	Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP+ Carbendazim 25 WP (0.15%) at 45 & 60 DAT	10.13	11.43
T10	Panchagavya 3% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT	8.96	9.66
T11	Panchagavya 3% at 45 DAT + (Iprodione 25 WP + Carbendazim 25 WP) (0.15%) at 60 DAT	10.07	10.43
T12	Jeevamrutha 20% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT	10.07	11.67
T13	Jeevamrutha 20% at 45 DAT + (Iprodione25WP + Carbendazim 25WP) (0.15%) at 60 DAT	18.57	12.50
T14	Effective Microorganisms 1% at 45 & 60 DAT	46.10	35.90
T15	*Pseudomonas fluorescens 2%* (Biocontrol check) as per PoP (KAU)	35.87	36.83
T16	Propiconazole 25 EC (0.1%) (Fungicidal check) at 45 & 60 DAT	7.76	10.37
T17	Control	56.43	60.23
	CD 5%	**3.644**	**4.00**

rice

DAT. Days After Transplanting

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spiklets/ panicle, number of filled grain per panicle, thousand grain weight, grain yield and straw yield were also calculated and the results are presented here under:

4.8.1. Disease reaction

4.8.1.1. Per cent disease incidence (PDI)

All the treatments were found significantly effective in managing the disease, when compared to the control (Table 18 and Fig 2). Among the various treatments, the plots which were sprayed with Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10) with PDI of 8.96 were found to be the most effective treatment in checking the disease and was on par with the standard fungicide Propiconazole 25 EC (0.1 %) with PDI of 7.76. The plots which were sprayed with Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (T9), and (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), Flusilazole 40 EC (0.15 %) (T3) and Vermicompost + Flusilazole 40 EC (0.15 %) (T8) ranked next with PDI of 10.07, 10.07, 10.13, 10.70, 11.17 and 12.08 respectively and were on par with each other. The treatment consisting of Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (T13) showed PDI of 18.57. All the above treatments were found on par with each other in checking the disease. The treatments which received *Pseudomonas fluorescens* 2% (T15), Jeevamrutha 20% (T2) Vermicompost + Panchagavya 3% (T6), Panchagavya 3% (T1), Vermicompost + Jeevamrutha 20% (T7) were found on par in managing the disease with PDI of 35.87, 36.50, 38.13, 39.63 and 41.70 respectively. The control (T17) recorded the maximum PDI of 56.43.

4.8.1.2. Per cent Disease Severity (PDS)

The Per cent Disease Severity (PDS) varied from 9.66 to 60.23 (Table 18 and Fig. 2). All the treatments were found significantly effective in managing the disease

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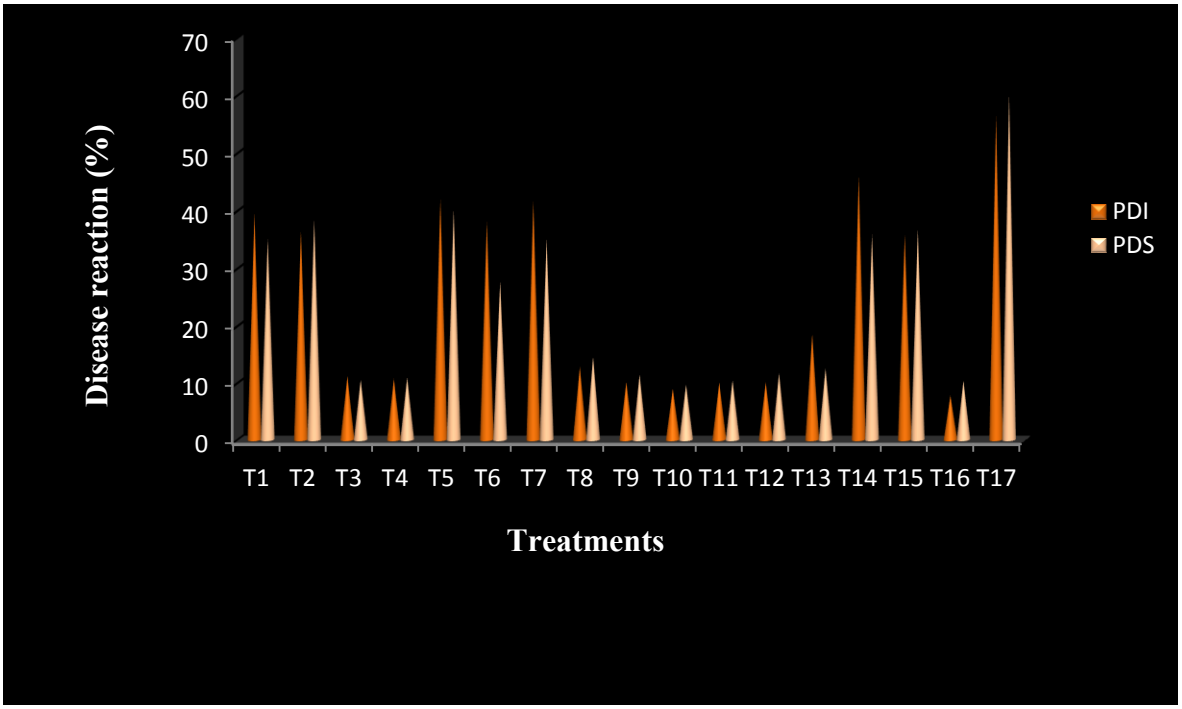
Fig 2. Evaluation of new generation fungicides and liquid organic formulations against sheath blight of rice under field condition (PDI and PDS)



T1.Panchagavya 3% at 45 & 60 DAT

T2.Jeevamrutha 20% at 45 & 60 DAT

T3.Flusilazole 40 EC (0.15%) at 45 & 60 DAT

T4.(Iprodione 25WP + Carbendazim 25WP) 0.15%) at 45 & 60 DAT

T5.Vermicompost @ 2.5 t/ha as basal

T6. Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP + Carbendazim 25 WP) (0.15%) at 45 & 60 DAT

T7. Vermicompost @ 2.5 t/ha as basal +Jeevamrutha 20% at45 & 60 DAT

T8. Vermicompost @ 2.5 t/ha as basal + Flusilazole 40 EC (0.15%) at 45 & 60 DAT

T9. Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP+ Carbendazim 25 WP (0.15%) at 45 & 60 DAT

T10. Panchagavya 3% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT

T11. Panchagavya 3% at 45 DAT + (Iprodione 25 WP + Carbendazim 25 WP) (0.15%) at 60 DAT

T12. Jeevamrutha 20% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT

T13. Jeevamrutha 20% at 45 DAT + (Iprodione25WP + Carbendazim 25WP) (0.15%) at 60 DAT

T14. Effective Microorganisms (EM)1% at 45 & 60 DAT

T15. *Pseudomonas fluorescens 2%* (Biocontrol check) as per PoP (KAU)

T16. Propiconazole 25 EC (0.1%) (Fungicidal check) at 45 & 60 DAT

T17 .Control

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than control. Among the various treatments, the plots which were sprayed with Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10) ranked first with PDS of 9.66. Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11 with PDS of 10.43), Flusilazole 40 EC (0.15 %) (T3 with PDS of 10.53), + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4 with PDS of 10.93), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9-11.43), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12-11.67), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13-12.50) and Vermicompost + Flusilazole 40 EC (0.15 %) (T8-14.60) were ranked next in managing the disease. The treatments consisting of *viz.,* Vermicompost + Panchagavya 3% (T6), Panchagavya 3% (T1), Vermicompost + Jeevamrutha 20% (T7), EM 1% (T14), *Pseudomonas fluoresense* 2% standard biocontrol check (T15), Jeevamrutha 20% (T2) and Vermicompost (T5) stood next with PDS of 27.80 , 35.17, 35.20, 35.90, 36.83, 38.43 and 40.23 respectively. The absolute control (T17) recorded the maximum PDS of 60.23.

4.8.2. Effect of different treatments on biometric characters

The effects of different treatments on biometric characters of the plants were studied. The results are presented in Table 19.

4.8.2.1. Growth characters

4.8.2.2. Plant height (cm)

The effect of different treatments on plant height revealed that the treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Flusilazole 40 EC (0.15 %) (T3), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), EM 1% (T14) and Panchagavya 3% (T1) were found to be highly effective in increasing the plant height

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Table 19. Effect of new generation fungicides and liquid organic formulations on plant biometric characters under field condition

No of panicles/hill	Treatments	Plant height	No. of productive	No of spiklets/ panicle	No of filled grains/	1000 Grain weight(g)	Grain yield (kg/ha)	Straw yield (kg/ha)
8.33 abcde	T1	98.17 abcd	400.85 a	76.33 abcd	48.33 defg	28.37 abc	4156 ab	7056 b
8.00 abcdef	T2	97.67 bcde	346.0 cd	75.00 abcd	45.00 fgh	26.77 cd	4112 ab	6628 de
7.00 cdefg	T3	99.33 abc	339.85 d	73.33 abcd	52.33 cde	27.13 bcd	4094 ab	6767 cd
6.66 cdefg	T4	98.17 abcd	344.5 cd	67.00 de	50.00 cdef	28.47 abc	4039 abc	6783 cd
7.66 abcdef	T5	93.69 g	277.0 f	68.00 de	41.33 h	27.03bcd	3739 d	6556 e
8.66 abcde	T6	97.50 bcde	406.0 a	78.67 abc	48.00 efg	28.10 abc	4172 ab	6628 de
6.33 defg	T7	94.67 fg	358.15 c	71.00 bcd	47.00 efgh	26.70 cd	4156 ab	6833 c
7.33 bcdefg	T8	96.83 cdef	335.0 d	76.33 abcd	54.67 bcd	25.20 d	4067 ab	6761 cd
9.33 abcd	T9	98.50 abcd	327.85 d	70.00 cde	49.67 cdef	26.77 cd	4089 ab	6744 cd
10.67 a	T10	100.50 a	416.35 a	80.67 ab	60.00 ab	29.33 ab	4189 a	7300a b
9.00 abcde	T11	99.50 ab	412.0 a	82.67 a	61.00 a	27.10 bcd	4117 ab	7033 a
6.00 efg	T12	97.17 bcdef	384.5 b	69.33 cde	49.00 defg	29.97 a	4167 ab	6756 cd
9.33 abcd	T13	96.50 def	386.5 b	72.33 bcd	52.00 cde	26.43 cd	4183 a	6478 e
5.00 fg	T14	98.17 abcd	330.15 d	73.33 abcd	46.00 efgh	28.33 abc	4022 abc	6506 e
10.33 abc	T15	95.33 efg	299.65 e	71.67 bcd	42.67 gh	26.70 cd	3889 c	5900 f
9.66 ab	T16	97.17 bcdef	296.15 e	74.67 abcd	55.67 abc	28.47 abc	4006 bc	6778 cd
4.33 g	T17	89.33 h	243.85 g	61.00 e	32.67 i	22.40 e	2922 e	4272 g
2.744	CD 5%	2.249	16.39	8.688	5.553	2.125	141.3	162.0

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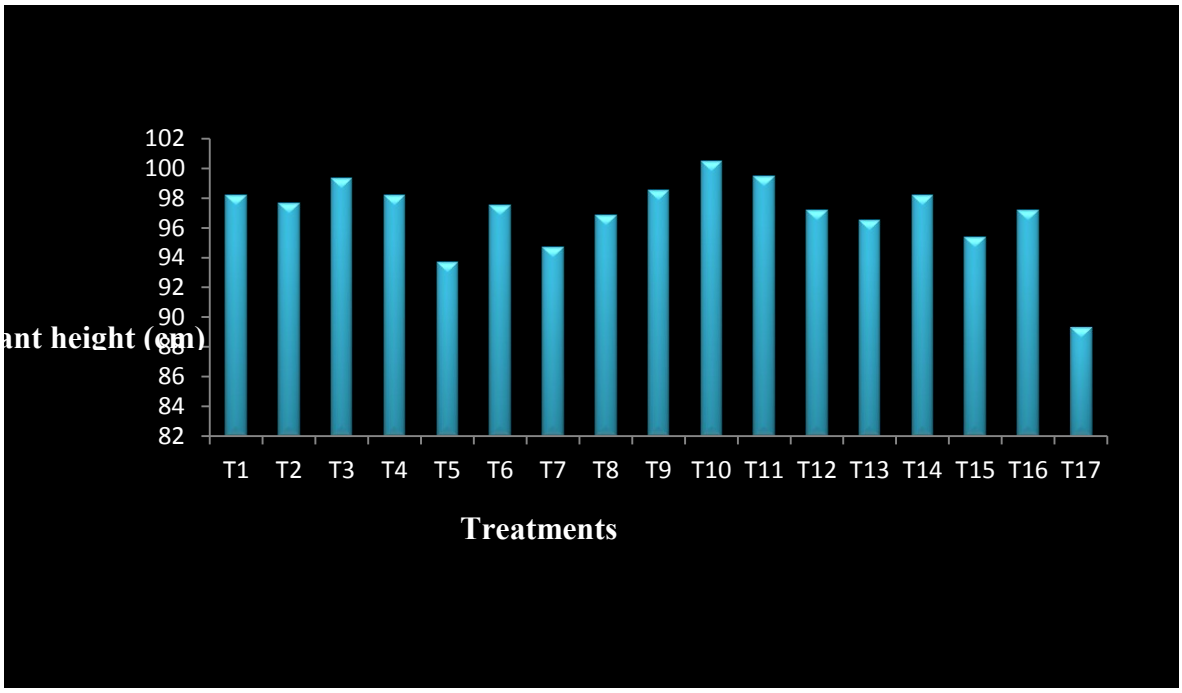
Fig 3. Effect of treatments on plant height (cm)



T1.Panchagavya 3% at 45 & 60 DAT

T2.Jeevamrutha 20% at 45 & 60 DAT

T3.Flusilazole 40 EC (0.15%) at 45 & 60 DAT

T4.(Iprodione 25WP + Carbendazim 25WP) 0.15%) at 45 & 60 DAT

T5.Vermicompost @ 2.5 t/ha as basal

T6. Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP + Carbendazim 25 WP) (0.15%) at 45 & 60 DAT

T7. Vermicompost @ 2.5 t/ha as basal +Jeevamrutha 20% at45 & 60 DAT

T8. Vermicompost @ 2.5 t/ha as basal + Flusilazole 40 EC (0.15%) at 45 & 60 DAT

T9. Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP+ Carbendazim 25 WP (0.15%) at 45 & 60 DAT

T10. Panchagavya 3% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT

T11. Panchagavya 3% at 45 DAT + (Iprodione 25 WP + Carbendazim 25 WP) (0.15%) at 60 DAT

T12. Jeevamrutha 20% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT

T13. Jeevamrutha 20% at 45 DAT + (Iprodione25WP + Carbendazim 25WP) (0.15%) at 60 DAT

T14. Effective Microorganisms (EM)1% at 45 & 60 DAT

T15. *Pseudomonas fluorescens 2%* (Biocontrol check) as per PoP (KAU)

T16. Propiconazole 25 EC (0.1%) (Fungicidal check) at 45 & 60 DAT

T17 .Control

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(Fig 3). They showed the mean plant height of 100.50, 99.50, 99.33, 98.50, 98.17, 98.17 and 98.17 cm respectively. The treatments *viz.,* Jeevamrutha 20% (T2), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Propiconazole 25 EC (0.1 %) (T16), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12) were found next in increasing the plant height. They showed the mean plant height of 97.67, 97.50, 97.17 and 97.17cm respectively. The treatments *viz*., Vermicompost + Flusilazole 40 EC (0.15 %) (T8), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13), *Pseudomonas fluorescens* 2% (T15), Vermicompost + Jeevamrutha 20% (T7), Vermicompost (T5) were found on par with the mean plant height of 96.83, 96.50, 95.33, 94.67, and 93.69 cm respectively. The control (T17) recorded a mean shoot length of 89.33 cm only.

4.8.2.3. Number of productive tillers/m^2

The effect of different treatments on number of productive tillers revealed that the treatments *viz.,* Panchagavya 3% (T1), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), were found to be highly effective in increasing the number of tillers with mean tiller number of 400.85, 406.0, 412.0 and 416.35 respectively. The treatments which received Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Vermicompost + Jeevamrutha 20% (T7) were found next in increasing the tiller numbers with the mean tiller number of 386.5, 384.5 and 358.15 respectively. The treatments which received Jeevamrutha 20% (T2), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), Flusilazole 40 EC (0.15 %) (T3), Vermicompost + Flusilazole 40 EC (0.15 %) (T8), EM 1% (T14), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9) were found on par with the mean tiller numbers of 346.0, 344.5, 335.0, 330.15 and 327.85 respectively. The treatments consisting of *Pseudomonas fluorescens* 2%

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(T15), Propiconazole 25 EC (0.1 %) (T16), Vermicompost (T5) showed a minimum tiller number of 299.65, 296.15 and 277.0 respectively. The control (T17) recorded the lowest tiller number of 243.85.

4.8.3. Yield attributes

4.8.3.1. Number of panicles/hill

The effect of different treatments on the number of panicles revealed that the treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Propiconazole 25 EC (0.1 %) (T16), *Pseudomonas fluorescens* 2% (T15), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), were found highly effective in increasing the number of panicles with mean panicle numbers of 10.67, 10.33, 9.66, 9.33, 9.33 and 9.00 respectively. Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Panchagavya 3% (T1), Jeevamrutha 20% (T2), Vermicompost (T5), Vermicompost + Flusilazole 40 EC (0.15 %) (T8), Flusilazole 40 EC (0.15 %) (T3) were found next in increasing the panicle numbers with the mean panicle number of 8.66, 8.33, 8.00, 7.66, 7.33, and 7.0 respectively. The treatments *viz.,* (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), Vermicompost + Jeevamrutha 20% (T7), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), EM 1% (T14) was found least in increasing the panicle number of 6.667, 6.33, 6.00 and 5.00. The control (T17) recorded the minimum panicle number of 4.33.

4.8.3.2. Number of spiklets/panicle

The effect of different treatments on number of spiklets per panicle showed that the plots which received the treatments *viz.,* Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Panchagavya 3% + Flusilazole 40 EC (0.15

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%) (T10), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Panchagavya 3% (T1), Vermicompost + Flusilazole 40 EC (0.15 %) (T8) were found significant in increasing the number of spiklets per panicle with mean spikelet numbers of 82.67, 80.67, 78.67, 76.33 and 76.33 respectively. The treatments *viz.,* Jeevamrutha 20% (T2), Propiconazole 25 EC (0.1 %) (T16), Flusilazole 40 EC (0.15 %) (T3), EM 1% (T14) Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13) were found next in increasing the mean spikelet number of 75.00, 74.67, 73.33, 73.33 and 72.33 respectively. The treatments *viz., Pseudomonas fluorescens* 2% (T15), Vermicompost + Jeevamrutha 20% (T7), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Vermicompost (T5), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4) were found lowest in increasing the spikelet number 71.67, 71.00, 70.00, 69.33, 68.00 and 67.00 respectively. The control (T17) recorded the minimum spikelet number of 61.00.

4.8.3.3. Number of filled grains per panicle

The effect of different treatments on number of filled grains per panicle revealed that the plots which received the treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC 0.15 %) (T10), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11) were found significantly superior in increasing the number of filled grains per panicle. They showed the mean values of 61.00 and 60.00 respectively. The treatments *viz.,* Propiconazole 25 EC (0.1 %) (T16), Vermicompost + Flusilazole 40 EC (0.15 %) (T8), Flusilazole 40 EC (0.15 %) (T3), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13) were ranked next with the number of filled grains of 55.67, 54.67, 52.33 and 52.00 respectively. The treatments *viz.,* (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Panchagavya 3% (T1),

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Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6) were found on par and showed the mean number of 50.00, 49.67, 49.00, 48.33 and 48.00 respectively. The treatments *viz.,* Vermicompost + Jeevamrutha 20% (T7), EM 1% (T14) Jeevamrutha 20% (T2), *Pseudomonas fluorescens* 2% (T15), Vermicompost (T5) were found on par with the mean number of filled grains of 47.00, 46.00, 45.00, 42.67 and 41.33 respectively. The control (T17) recorded the least number of filled grains of 32.67.

4.8.3.4. Thousand grain weight (g)

The effect of different treatments on the thousand grain weight showed that the plots which received the treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Propiconazole 25 EC (T16), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), Panchagavya 3% (T1), EM 1% (T14), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6) were found significantly superior in increasing the grain weight with the mean thousand grain weight of 29.97 , 29.33 , 28.47, 28.47, 28.33 and 28.10 g respectively. The treatments *viz.,* Flusilazole 40 EC (0.15 %) (T3), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Vermicompost (T5) was ranked with thousand grain weight of 27.13, 27.10 and 27.03 respectively. The treatments *viz.,* Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), Jeevamrutha 20% (T2), Vermicompost + Jeevamrutha 20% (T7), *Pseudomonas fluorescens* 2% (T15), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13) stood next with the mean thousand grain weight of 26.70 g. followed by Vermicompost + Flusilazole 40 EC at (0.15 %) (T8) with the mean thousand grain weight of 25.20g and were on par with each other. The control (T17) recorded the minimum mean thousand grain weight of 22.40g.

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4.8.3.5. Grain yield (kg/ha)

The plots which received the treatment Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10) and Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13) recorded significantly higher yields of 4189 kg/ha and 4183 kg/ha respectively (Table 19 and Fig 4). The treatments *viz.,* Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Vermicompost + Jeevamrutha 20% (T7), Panchagavya 3% (T1), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Jeevamrutha 20% (T2) were found next in enhancing the yield of 4172, 4167, 4156, 4156, 4117 and 4112 kg/ha respectively. The treatments *viz.,* Flusilazole 40 EC (0.15 %) (T3), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), Vermicompost + Flusilazole 40 EC (0.15 %) (T8), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), EM 1% (T14), Propiconazole 25 EC (0.1 %) (T16) were found on par with the yield of 4094, 4089, 4067, 4039, 4022 and 4006 kg/ha respectively. The treatments *viz., Pseudomonas fluorescens* 2% (T15) and Vermicompost (T5) were found on par yield of 3889 and 3739 kg/ha. The control (T17) recorded the lowest yield of 2922 kg/ha.

4.8.3.6. Straw yield (Kg/ha)

The plots which received the treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Panchagavya 3% (T1) and Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11) were found significantly superior over the treatments in increasing the straw yield (Table 19 and Fig 4). They showed the mean straw yield of 7300, 7056 and 7033 kg/ha respectively. The treatments *viz.,* Vermicompost + Jeevamrutha 20% (T7), (Iprodione 25 WP + Flusilazole 40 EC (0.15 %) (T3), Vermicompost + Flusilazole 40

(T16), (T8), Jeevamrutha 20% + Flusilazole 40

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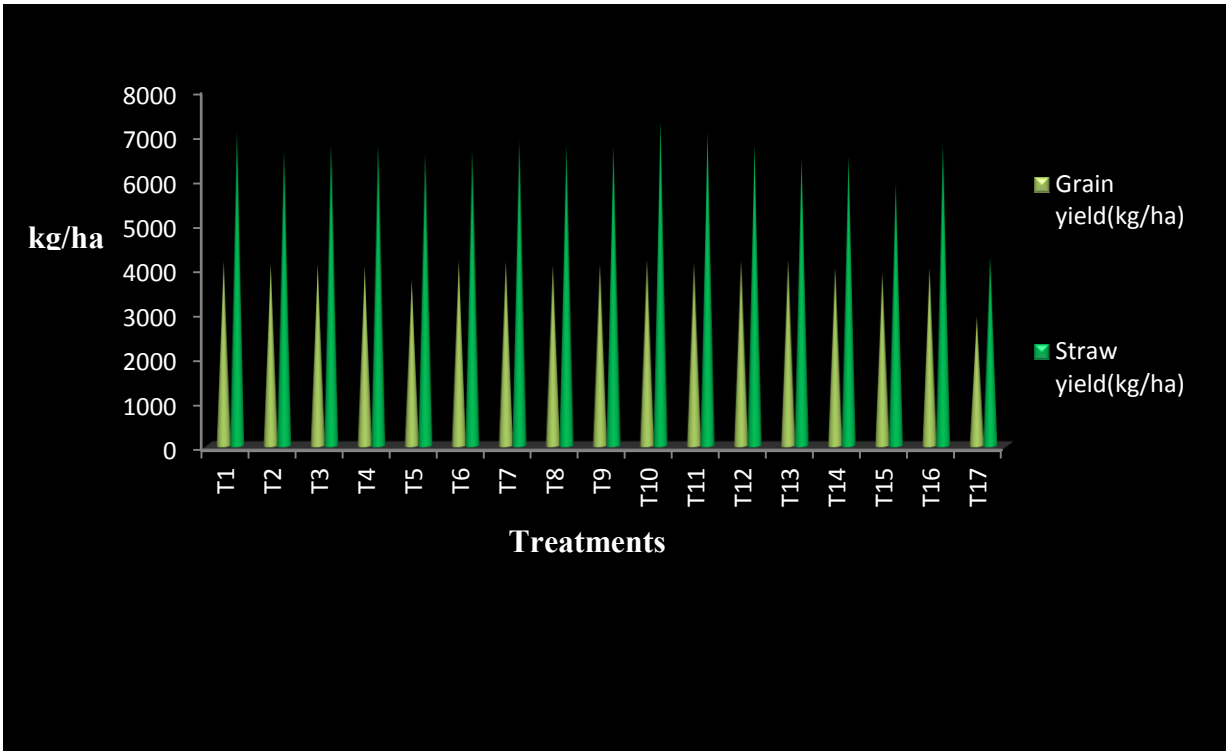
Fig 4. Effect of treatments on yield of paddy (kg/ha)



T1.Panchagavya 3% at 45 & 60 DAT

T2.Jeevamrutha 20% at 45 & 60 DAT

T3.Flusilazole 40 EC (0.15%) at 45 & 60 DAT

T4.(Iprodione 25WP + Carbendazim 25WP) 0.15%) at 45 & 60 DAT

T5.Vermicompost @ 2.5 t/ha as basal

T6. Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP + Carbendazim 25 WP) (0.15%) at 45 & 60 DAT

T7. Vermicompost @ 2.5 t/ha as basal +Jeevamrutha 20% at45 & 60 DAT

T8. Vermicompost @ 2.5 t/ha as basal + Flusilazole 40 EC (0.15%) at 45 & 60 DAT

T9. Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP+ Carbendazim 25 WP (0.15%) at 45 & 60 DAT

T10. Panchagavya 3% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT

T11. Panchagavya 3% at 45 DAT + (Iprodione 25 WP + Carbendazim 25 WP) (0.15%) at 60 DAT

T12. Jeevamrutha 20% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT

T13. Jeevamrutha 20% at 45 DAT + (Iprodione25WP + Carbendazim 25WP) (0.15%) at 60 DAT

T14. Effective Microorganisms (EM)1% at 45 & 60 DAT

T15. *Pseudomonas fluorescens 2%* (Biocontrol check) as per PoP (KAU)

T16. Propiconazole 25 EC (0.1%) (Fungicidal check) at 45 & 60 DAT

T17 .Control

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EC (0.15 %) (T12), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9) were found on par with the mean straw yield of 6833, 6783, 6778, 6767, 6761, 6756 and 6744 kg/ha respectively. The treatments *viz.,* Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Jeevamrutha 20% (T2), Vermicompost (T5), EM 1% (T14), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15%) (T13), *Pseudomonas fluorescens* 2% (T15) were found on par with the mean straw yield of 6628, 6628, 6556, 6506, 6478 and 5900 kg/ha. The control (T17) recorded the minimum straw yield of 4272 kg/ha (Fig 3).

4.9. Benefit: Cost (BC) ratios for integrated disease management of sheath blight using liquid organic formulations and new generation fungicides in rice cultivation

BC ratios were computed for each treatment by considering the total cost and returns. The results are presented in Table 20 and Fig 5. It was observed that the highest BC ratio of 1.61 was obtained with Panchagavya 3% + Flusilazole 40 EC at (0.15 %) (T10). This treatment also recorded the highest returns (Rs. 94191Rs $ha^{-1)}$ followed by Panchagavya 3% (T1) which obtained the BC ratio of 1.59 and the treatments *viz.,* T7 (Vermicompost + Jeevamrutha 20%), T11 (Panchagavya 3% + Iprodione 25 WP + Carbendazim 25 WP(0.15 %), T12 (Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) were found next increasing the BC ratio of 1.57. The treatments *viz.,* T3 Flusilazole 40 EC (0.15 %), T6 Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) and T13 Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) recorded the BC ratio of 1.53. The treatments *viz.,* Jeevamrutha 20% (T2), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), Vermicompost + Flusilazole 40 EC (0.15 %) (T8), Propiconazole 25 EC (0.1%) (T16), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), EM 1% (T14), *Pseudomonas fluorescens* 2% (T15) and Vermicompost (T5) were found on par with BC ratios of 1.55, 1.55, 1.54, 1.53, 1.53, 1.53, 1.46 and 1.43 respectively. The control obtained the lowest BC ratio of 1.11.

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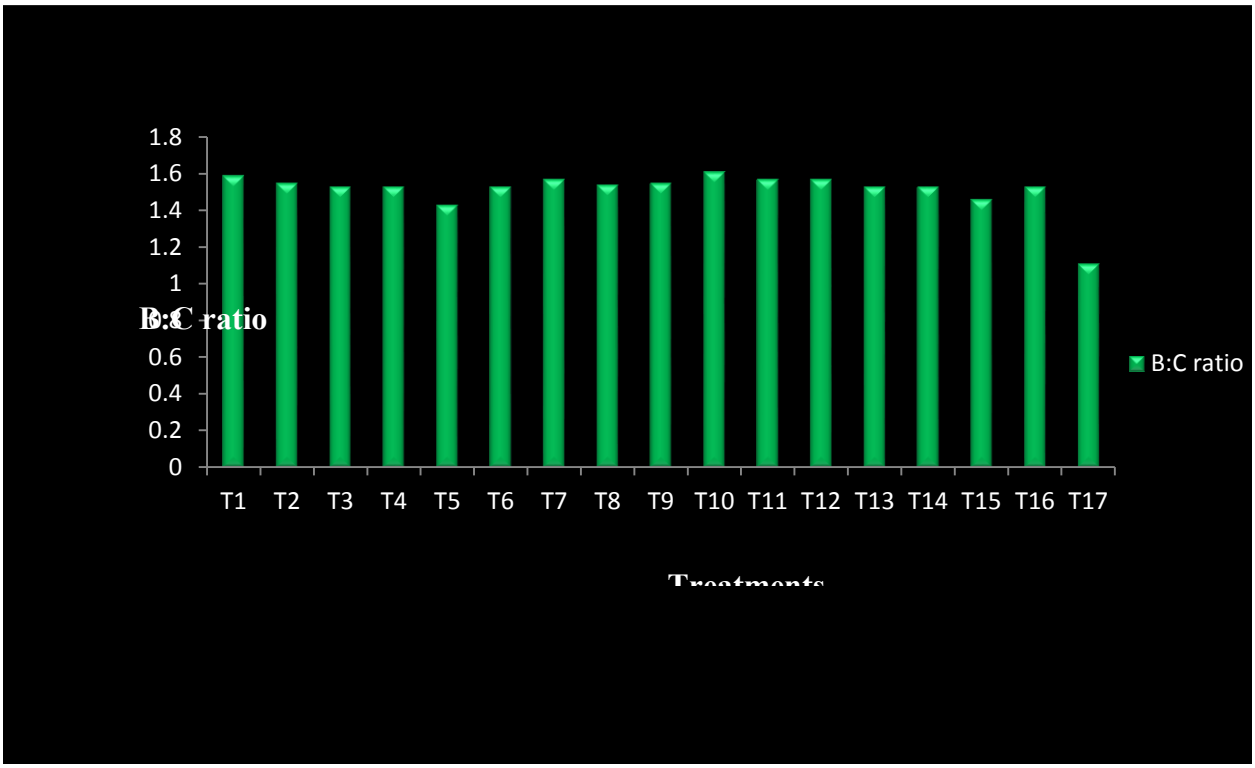
Table 20. Benefit : Cost (BC) ratios for integrated disease management of rice using liquid organic formulations and new generation fungicides in rice cultivation

Treatments	Cost of Production excluding treatments(Rs ha^{-1})	Additional cost of the treatments (Rs ha^{-1})	Total cost of Production (Y) Rs	Grain yield (Rs . ha^{-1})	Straw yield (Rs . ha^{-1})	Value X (Rs . ha^{-1})	Net profit (X-Y) Rs ha^{-1}	Benefit :cost ratio (X/Y)
T1	57542	1250	58792	78964	14112	93076	34284	1.59
T2	57542	1250	58792	78128	13256	91384	32592	1.55
T3	57542	1000	58542	77786	13534	91320	32778	1.53
T4	57542	1500	59042	76741	13566	90307	31265	1.53
T5	57542	1000	58542	71041	13112	84153	25611	1.43
T6	57542	1450	58992	79268	13256	92524	33532	1.53
T7	57542	1300	58842	78964	13666	92630	33788	1.57
T8	57542	1300	58842	77273	13522	90795	31953	1.54
T9	57542	1250	58792	77691	13488	91179	32387	1.55
T10	57542	850	58392	79591	14600	94191	35799	1.61
T11	57542	1250	58792	78223	14066	92289	33497	1.57
T12	57542	1350	58892	79173	13512	92685	33793	1.57
T13	57542	1250	58792	79477	12956	92433	33641	1.53
T14	57542	1000	58542	76418	13012	89430	32888	1.53
T15	57542	1150	58692	73891	11800	85691	26999	1.46
T16	57542	1000	58542	76114	13556	89670	31128	1.53
T17	57542	Nil	57542	55518	8544	64062	6520	1.11

Fig 5. B: C Ratios for the IDM of sheath blight using liquid organic formulations and new generation fungicides in rice cultivation



T1.Panchagavya 3% at 45 & 60 DAT

T2.Jeevamrutha 20% at 45 & 60 DAT

T3.Flusilazole 40 EC (0.15%) at 45 & 60 DAT

T4.(Iprodione 25WP + Carbendazim 25WP) 0.15%) at 45 & 60 DAT

T5.Vermicompost @ 2.5 t/ha as basal

T6. Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP + Carbendazim 25 WP) (0.15%) at 45 & 60 DAT

T7. Vermicompost @ 2.5 t/ha as basal +Jeevamrutha 20% at45 & 60 DAT

T8. Vermicompost @ 2.5 t/ha as basal + Flusilazole 40 EC (0.15%) at 45 & 60 DAT

T9. Vermicompost @ 2.5 t/ha as basal + (Iprodione 25WP+ Carbendazim 25 WP (0.15%) at 45 & 60 DAT

T10. Panchagavya 3% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT

T11. Panchagavya 3% at 45 DAT + (Iprodione 25 WP + Carbendazim 25 WP) (0.15%) at 60 DAT

T12. Jeevamrutha 20% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT

T13. Jeevamrutha 20% at 45 DAT + (Iprodione25WP + Carbendazim 25WP) (0.15%) at 60 DAT

T14. Effective Microorganisms (EM)1% at 45 & 60 DAT

T15. *Pseudomonas fluorescens 2%* (Biocontrol check) as per PoP (KAU)

T16. Propiconazole 25 EC (0.1%) (Fungicidal check) at 45 & 60 DAT

T17 .Control

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Discussion

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5.DISCUSSION

Sheath blight caused by *Rhizoctonia solani* Kuhn is one of the most important diseases of rice, inflicting heavy crop losses every year. In rice based intensified cropping system, edapho climatological and host variations make this disease problem more complicated. The subterranean nature and prolonged survival of sclerotia of *R. solani* in rice stubbles and in soil, render the chemical control less effective. Now a days, farmers widely use liquid organic formulations *viz*., Panchagavya, Beejamrutha, Jeevamrutha, Bio digester *etc.* as one of the components in the integrated disease management programme. So, scientific validation of these organic formulations as one of the components in integrated disease management is of high value. Hence, the present study was carried out with the following objectives: (i) Survey, collection and isolation of different isolates of *R.solani* from various locations of Thrissur district, Kerala (ii) Study on the Symptomatology of the disease (iii) Cultural and morphological characterization of different isolates of *R. solani* (iv) Cluster analysis of *R. solani* and its grouping (v) Estimation of microbial profile of liquid organic formulations at different periods of storage (vi) *In vitro* evaluation of liquid organic formulations and new generation fungicides against different isolates of *R. solani* (vii) Field experiment for the integrated management of sheath blight using liquid organic formulations, new generation and vermicompost. The results obtained from the present investigation given in the preceding chapters and discussed here under.

5.1. Survey on the occurrence of sheath blight disease in rice growing locations in Thrissur district of Kerala

Surveys were conducted in ten locations of Thrissur district of Kerala *viz.,* Mannuthy, Chirakekode, Ollukkara, Vellanikkara, Pattikkad, Madakathara, Chalakudy, Adat, Pudurkara and Irinjalakuda during August-September 2013 to study the occurrence of sheath blight disease. Per cent Disease Incidence (PDI) and Per cent Disease Severity (PDS) of sheath blight

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in ten rice growing locations of Thrissur district ranged from 24.53 to 51.95 and 44.76 to 85.53 respectively. The maximum PDI was recorded in paddy fields of Adat (51.95) followed by Irinjalakuda (49.18), Pudurkara (48.10), Chalakudy (48.10), Vellanikkara (46.83) and Madakathara (46.55) and were on par with each other. Pattikkad, Mannuthy and Chirakekode were ranked next and were on par as evidenced by the PDI of 37.40, 34.83 and 32.51 respectively. Of the ten locations surveyed, paddy fields of Ollukkara recorded the least PDI of 24.53. The PDS was also found to be maximum in paddy fields of Adat (85.53) and Chalakudy (84.30) followed by Pudurkara (81.76), Iranjalakuda (78.93) and Mannuthy (73.31) and were on par with each other. Chirakekode (64.30), Pattikkad (56.65), Ollukkara (53.03) and Vellanikkara (50.50) were ranked next as evidenced by the PDS. Of the ten locations surveyed, paddy fields of Madakathara recorded the least PDS of 44.76.

The survey was conducted during the vulnerable period from active tillering to flowering stage of the crop, which is highly prone to sheath blight development. The heavy incidence of sheath blight might be due to the highly favourable factors like high relative humidity, less temperature and water stagnation due to continuous rain on these locations during the period of survey. Large scale cultivation of farmer preferred susceptible varieties *viz.,* Jyothi (PTB-39) and Uma (MO-16) as monocrop continuously on the same field might have increased the possibility of perpetuating the pathogen in the crop debris. *R. solani* being soil borne in nature, besides thriving in weed hosts, it survives on mycelia and sclerotia left in field. Sclerotia remain viable in soil upto 270 days to a depth of 10 cm at the temperature level of 0-40 °C (Kannaiyan and Prasad, 1981; Sati and Sinha, 1999). Surveys conducted by Guleria *et al.* (2007) in Punjab and Jayaprakashvel and Mathivanan (2012) in Bangladesh on sheath blight occurrence opined that Per cent Disease Incidence (PDI) and Per cent Disease Severity (PDS) differ from one location to other and even from country and region wise and the difference in sheath blight severity might be attributed to the variation in host genotype, virulence

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spectrum of the pathogen isolates, prevalence of congenial soil physio-chemical and plant's micro climate and cultural practices.

5.2. Isolation of different *R. solani* isolates and pathogenicity test

The growth of the fungus developed on PDA medium was purified by repeated sub culturing on the same medium and pure cultures of the isolates were maintained. Based on the mycological characters, the pathogen was identified as *Rhizoctonia solani*. The pathogen was fast growing with light brown coloured colonies on PDA medium. Mycelium was hyaline when young and become yellowish brown when old with frequent septations. Branching of hyphae was occurred at right angles near the distal end of septum and constriction at the point of union with main hyphae, which were the characteristic features of the fungus. A total of ten isolates of *R. solani* were obtained from ten locations of Thrissur district and these ten isolates were selected for further studies. Similar mycological studies of *R. solani* had been carried out by earlier workers (Dugger, 1915; Palo, 1926 and Frederickson *et al.,* 1938).

Pathogenicity of all the isolates was proved by inoculating actively grown culture of *R. solani* on the susceptible variety, Jyothi (PTB-39) at the active tillering stage. Initial symptoms as small water soaked spots developed by all isolates on the third day of inoculation. Characteristic symptoms *viz*., circular to ovoid, irregular, water soaked, larger lesions developed within seven to ten days by all isolates. The pathogens were reisolated and compared with the original culture of *R. solani.* Kumar *et al.* (2009) while studying virulence diversity of 25 isolates of *R. solani*, found that appearance of water soaked oval to irregular spots within 48 to 96 h of inoculation by all the isolates on the susceptible variety, Swarna and the plants were severely blighted within 10- 12 days of inoculation.

5.3. Symptomatology of the disease

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5.3.1. Symptomatology under natural and artificial conditions

During the survey, symptoms were observed on main field at late tillering stage. It appeared initially as greenish grey, ellipsoid or ovoid, water soaked irregular lesions of one to three cm long. Centre of the spots greyish white with brown margins. The symptoms were started near the water line and spread upwards. Sclerotia were formed on or near these lesions and were detached early. Irregular greenish grey lesions with brown margins were observed on leaf lamina also. Under favourable condition, the disease spread very fast to adjacent tillers and caused death of whole plants. Similar types of symptoms were reported by Singh (1988) who observed water soaked circular to oblong, ellipsoid to ovoid, even irregularly elongated with pale, greenish grey to greyish white centre and narrow blackish to dark brown margin on sheath, culm, boot and flag leaf.

On artificial inoculation of *R. solani* on 45 days old Jyothi (PTB-39) rice plants, all the isolates showed the initial symptom; small water soaked, greenish grey lesions within third day of inoculation. Later these lesions enlarged as ellipsoid to ovoid irregularly elongated lesions with pale, greenish grey to greyish white centre and narrow dark brown margins which were observed on leaf sheath and on leaf blades within seven to ten days of inoculation by all isolates. Finally four to five such lesions coalesced and girdled the whole leaf sheath and culm. Park *et al.* (2008) developed new methods for effective and uniform infection and accurate evaluation of sheath blight disease and found that liquid cultured mycelial balls caused significantly longer lesions on artificial inoculation.

5.4. Characterization of different isolates of *R. solani*

R. solani, one of the most important pathogens of rice in tropical agro - ecosystems, exists with great variations among the isolates in terms of mycelial colour, zonation, size and number of sclerotia, growth rate and pathogenicity (Hyakumachi *et al.,* 1998). So, characterization and analysis of variability existing among the different isolates is of great importance for the effective and successful

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management of the disease and hence the study.

The mycelial characters *viz.,* colour, texture and type of mycelia, sclerotial characters *viz.,* initiation and maturation of sclerotia, number of sclerotia per plate at 10, 15 and 20 Days After Incubation (DAI), weight of 50 sclerotia, sclerotial distribution and exudation rate of sclerotia were studied on four different media *viz.,* Potato Dextrose Agar (PDA) medium, Rose Bengal Agar (RBA) medium, Czapek's Dox Agar (CDA) medium and Richard's Agar (RA) medium. The growth rate of the ten isolates was also studied at 24 h interval on Petri plates mediated with PDA till the pathogen attained full growth.

Among the ten isolates of *R. solani* tested on PDA medium, nine isolates produced light brown colonies except ShVKA4, where it produced whitish brown colonies. In RBA, CDA and RA medium, all the ten isolates produced whitish brown colonies. Mycelial texture was smooth on PDA in six isolates *viz.,* Sh CKD2, Sh VKA4, Sh MDTA6, Sh CKDY7, Sh ADT8 and Sh IRJK10 whereas the remaining four were rough textured. In RBA, all the ten isolates were smooth textured whereas in CDA, nine isolates produced rough textured colonies except Sh VKA4 where it produced smooth colonies. In RA medium seven isolates *viz.,*Sh MTY1, Sh CKD2, Sh OKRA3, Sh VKA4, Sh MDTA6, Sh CKDY7 and Sh ADT8 were smooth textured and the remaining three were of rough textured. On PDA, fluffy type mycelial growth was observed by six isolates whereas the remaining four isolates were of compact type. In RBA, all isolates produced compact type of mycelium whereas in CDA eight isolates were with compact type and the remaining were of fluffy type mycelia. In RA, all the ten isolates were with compact mycelium.

On PDA, sclerotial initiation by ten isolates ranged from five to six days and its maturation was observed within six to nine days, whereas in RBA, sclerotial initiation was observed within five to six days. In CDA and RA media, the sclerotial initiation was on seventh day and its maturation was on ninth day. Production of sclerotia by the ten isolates at 10, 15 and 20 DAI, revealed that

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there was gradual increase in the number of sclerotia at 10, 15 and 20 DAI. At 10 DAI sclerotial population on PDA ranged from 24 to 34 per plate whereas at 15 DAI, it was 30- 37 per plate and it reached a level of 40 to 49 at 20 DAI. A similar trend was observed in RBA also, whereas in CDA and RA comparatively lesser number of sclerotia were observed. Mean weight of 50 sclerotia of ten isolates of *R.solani* also showed a high degree of variation on four different media. The minimum weight ranged from 190 to 160 mg whereas the maximum weight was between 310 to 364 mg.

Growth rate of ten isolates of *R. solani* on PDA revealed that within 24 h, six isolates spread to more than half of the Petri plate and all the isolates were fully covered within third day of inoculation. On RBA, all the ten isolates spread to more than half of the Petri plate within 48 h and took four days for the complete coverage of the Petri plate. In CDA and RA media, the isolates took 72 h to cover more than half of the Petri plate and by the fifth day, the isolates completely covered the Petri plate.

In conclusion, PDA and RBA media supported the maximum mycelial growth and sclerotial production while minimum mycelial growth and sclerotial production were observed in CDA and RA media. Growth rate of different isolates on four different media revealed that all the ten isolates grew faster on PDA and RBA, whereas on CDA and RA media, growth rate of the ten isolates of *R. solani* were comparatively slow.

R. solani Kuhn (telomorph; *Thantephorus cucumeris*), being a wide spread, ecologically diverse soil-borne pathogen, many attempts were made by the researchers to organize *R. solani* into groups, on the basis of cultural, morphological and pathological characters (Sherwood, 1969; Singh *et al.,* 2002; Sharma *et al.,* 2005). The results of the present study are in line with that of Meena *et al.* (2001), who studied the morphological and cultural characters of *R.solani* isolates of Tamil Nadu state (locations- Madurai, Melur, Coimbatore, Trichy and Arumbanur) and found that the mycelial and sclerotial characters of

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R.solani varied greatly among the isolates. Madurai isolate grew faster and produced dark brown mycelium and larger sized, dark brown sclerotia on PDA medium. Small, light brown sclerotia were produced by Trichy isolate. PDA medium supported the maximum mycelial growth and sclerotial production, while the minimum mycelial growth and sclerotial production were found in CDA medium.

Cultural characterization of 12 isolates of *R. solani* of rice from West Bengal was done by Basu *et al.* (2004) and found that the isolates *viz.,* R1, R5, R7, R9 and R11 showed luxuriant to abundant arial mycelium whereas R2 and R3 showed moderate to sparse mycelium. Colony colour ranged from creamy (R5 and R7) to light brown (R1, R2, R3, R9, R11 and R12). Sclerotia were not differentiated in isolates R3 and R5. Sclerotial production was poor in isolates R1 and R7, fair in R12 and good in R2, R9 and R11. Sclerotial size was largest in R9 and smallest in isolate R2. Guleria *et al.* (2007) collected 19 isolates of *R. solani* from various regions of Punjab and studied their morphological characters. Majority of the isolates were fast growers with raised and fluffy colonies and hyphal width of 9.6 µm, while four exhibited moderate growth rate. Colony colour in all, except the two isolates was light yellowish brown. There was no relationship between morphologically similar isolates.

Jayaprakashvel and Mathivanan (2012) studied morphological and pathological variations of 236 south Indian isolates of *R. solani* inciting rice sheath blight obtained from 45 locations. Sclerotial features such as colour, size, shape and distribution pattern were varied among the isolates. Majority of *R. solani* isolates were fast growers and they attained complete mycelial growth within two days and the emergence of sclerotial structures was seen even in four days of incubation. Kuiry *et al.* (2013) collected 67 isolates of *R. solani* from West Bengal and cultural and morphological characteristic studies were conducted and observed that, the diversity among the *R. solani* isolates does not correlate with their origin. Thus for the characterization of different *R. solani* isolates, number of sclerotia, hyphal length, weight of sclerotia and growth rate of

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the pathogen are the important morphological markers.

5.4.1. Cluster analysis of *R.solani* isolates based on morphological and cultural characters

The cultural and morphological characters of various isolates of *R. solani* were subjected to cluster analysis. Clustering was done as per UPGMA method of Sneath and Sokal (1973). The clustering pattern of *R. solani* isolates revealed a high degree of variability. There were two clusters A and B. In cluster A, higher similarity co-efficient of 0.69 was recorded between Sh MTY1, ShADT8 and Sh OKRA3 (Fig. 1). Cluster A was further divided into two sub clusters A1 and A2. In sub cluster A1, the highest similarity coefficient of 0.78 was recorded between isolates ShMTY1, ShADT8, ShOKRA3, ShIRJK10 and ShPTKA9 whereas lowest similarity index of 0.75 was recorded between isolates ShCKD2, ShVKA4 and ShPKD5 in sub cluster A2. Cluster B had no sub clusters and it showed the similarity index of 0.67 between the isolate of ShCKD2 and ShCKDY7.

Similar type of characterization were done by Kuiry *et al.* (2013) through *K*-means cluster analysis and classified 67 isolates of *R. solani* from West Bengal in to five cluster groups on the basis of their morphological characters *viz.,* time taken for sclerotial formation, hyphal length, association of sclerotia and number of sclerotia. Hajara (2011) studied cultural and morphological characters of 11 isolates of *Sclerotium rolfsii* by using UPGMA method and revealed that 11 isolates showed the dissimilarity among them. Based on the UPGMA, dissimilarity matrix was constructed

5.5. Studies on the microbial profile of liquid organic formulations at different intervals

For any biological formulation, a safe and viable storage period is of high value for its efficient use in management of pests and diseases. So assessment of the microbial profile at definite intervals is essential before applying against a particular pathogen. Estimation of Total Microbial Count

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(TMC) is generally used as an acceptability index in standards, guidelines and specifications (Olafsdottir *et al*., 1997).

The microbial profile of Panchagavya, Dasagavya and Jeevamrutha was estimated at different intervals *viz.,* 25, 60, 90, 120 and 210 Days After Preparation (DAP). The total bacterial population of Panchagavya at 25 DAP was high, *i.e*., 97.33, 90.33 and 87 × 10^5 cfu/ml respectively followed by *Pseudomonas* spp. (90.66, 78.66 and 80.33 × 10^5 cfu/ml respectively). Fungal population was less (28.0, 27.66 and 28.0 × 10^4 cfu/ml). At 60 and 90 DAP, the population of bacteria, *Pseudomonas* and fungi in all the three liquid formulation had shown the same trend (bacterial profile – 93.66 - 95.0, 88.0 – 89.66, 81.0-89.66 × 10^5 cfu/ml), profile of *Pseudomonas* spp. 85.0-90.66, 75.66-78.66, 76.0-82.33 × 10^5 cfu/ml and fungal profile 24.66- 27.33, 27.0-28.0, 24.0-26.0 × 10^4 cfu/ml. At 120 DAP, fungal profile of Panchagavya and Jeevamrutha increased from 24.66 to 34.0 × 10^4 cfu/ml and from 24.0 to 33.0 × 10^4 cfu/ml respectively, whereas in Dasagavya, fungal profile had shown a slight decrease from 27.0 × 10^4 cfu/ml to 24.0 × 10^4 cfu/ml.

Total bacterial profile of all the three liquid organic formulations remained to be high up to 120 DAP. At 210 DAP, bacterial profile of Panchagavya decreased from 90.66 to 64.0 × 10^5 cfu/ml, Dasagavya from 86.66 to 67.0 × 10^5 cfu/ml and Jeevamrutha from 82.0 to 64.0 × 10^5 cfu/ml. But there was an increase in fungal population in all the three formulations *i.e.,* Panchagavya from 34.0 to 42.0 × 10^4 cfu/ml, Dasagavya from 24.0 to 48.0 × 10^4 cfu/ml and in Jeevamrutha 33.0 to 39.0 × 10^4 cfu/ ml. Actinomycetes colonies were not observed in any of the samples tested.

From the present study, it is concluded that the liquid organic formulations *viz.,* Panchagavya, Dasagavya and Jeevamrutha had a high microbial profile. Bacterial population was maximum upto 120 DAP and at 210 DAP, it was slightly decreased, whereas the fungal population was found to increase. No actinomycetes growth was observed in any of the samples tested during the period. Growth of actinomycetes might have got suppressed due to the increased

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population of bacteria and fungi. The present study revealed that the three liquid organic formulations *viz*., Panchagavya, Dasagavya and Jeevamrutha can be safely stored upto a period of 120 days without losing its viability. Panchagavya and Jeevamrutha were identified as rich sources of beneficial microbes, effective at very low dilutions and they also act as plant tonic (Palekar, 2006; Vasanthakumar, 2006). Sreenivasa *et al*. (2011) revealed that population of bacteria, fungi and actinomycetes in Panchagavya and Jeevamrutha ranged from 20.4-26.1 x 10^5 cfu/ml, 13.8-18.0 x 10^4 cfu/ml and 3.6-4.2 x 10^3 cfu/ml respectively and the other beneficial microbes like nitrogen fixers and P-solubilizers were also estimated in the study with a population range of 2.7-5.0 x 10^2 and 3.6-4.2 x 10^2 cfu/ml respectively.

5.6. Management of sheath blight of rice

Conducting experiments *in vitro* is mandatory pre-requisite for venturing into actual field experiments. Learning from the *in vitro* experiments, field experiments were carried out.

5.6.1. *In vitro* evaluation of liquid organic formulations and new generation fungicides against different isolates *R. solani*

In vitro evaluation of various liquid organic formulations *viz*., Panchagavya at 2 and 3%, Dasagavya at 2 and 3%, Jeevamrutha at 10 and 20% and *P. fluorescens* 2% (Biocontrol check) were carried out against different isolates of *R. solani.* The study revealed that Jeevamrutha at 10 per cent concentration showed maximum inhibition of 85.18 per cent which was on par with Jeevamrutha 20% (79.62). Panchagavya at 3 and 2% ranked next with per cent inhibition of 80.73 and 76.29 respectively. Dasagavya at 3and 2 % were ranked next with per cent inhibition of 79.25 and 76.66 respectively.

It is evident from the present study that the liquid organic formulations have been effective in reducing the growth of *R. solani*. According to Iyonova *et al.* (2001) Panchagavya is the fermented organic manure with high microbial load

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which include Effective Microorganisms (EM) and Methylotrophs profile bacteria (MPB). Sumangala and Patil (2009) evaluated Panchagavya under *in vitro* against grain discolouration fungus of rice, *Curvularia lunata* and Panchagavya had shown Per cent inhibition of 86.30 of mycelium and 95.90 percent inhibition of spores of *C. lunata.*

In vitro evaluation of new generation fungicides *viz*., Kresoxim methyl 44 SC (0.1 %), Pencycuron 25 SC (0.15 %), Flusilazole 40 EC (0.15 %), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) and Propiconazole 25 EC (0.1 %) (Fungicidal check) were tried under *in vitro* and revealed that Flusilazole 40 EC (0.15 %) and (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) showed 100 percent inhibition over control. Pencycuron 25 SC (0.15 %) ranked next with percent inhibition of 86.66 followed by Kresoxim methyl 44 SC (0.1 %) with per cent inhibition of 74.44. The standard fungicide Propiconazole 25 EC (0.1 %) also showed 100 per cent inhibition over control.

In conclusion Flusilazole 40 SC and Iprodione 25 WP + Carbendazim 25 WP selected in the present study had shown 100 per cent inhibition against all ten isolates of *R. solani.* This might be due to the following fungicidal action of these two new generation fungicides. Flusilazole is the first fungicide in the series of silicon-silyl triazole group, which is organic in nature with systemic action, comes under the umbrella of Ergosterol Biosynthesis Inhibitor (EBI) which makes the fungal membrane rigid and leaky, so that the hyphae of the pathogen cannot grow further and blocks elongation of primary hyphae (Itoh, 2000). Iprodione 25 WP + Carbendazim 25 WP is combination product having both systemic and contact mode of action. It inhibits the growth of fungal mycelium, thus affecting cell division, DNA and RNA synthesis and metabolism (Jacques, 1994). Lenka and Bhaktavatsalam (2011) while conducting experiments with the newer fungicides *viz.,* Azoxystrobin 25SC (0.75 and 1.0ml/litre), Flusilazole 40EC (0.6ml/litre) and Epoxyconazole 75 EC (3.0 ml/litre), revealed that the fungicides Azoxystrobin 25 SC @ 1.0 ml/litre was the most effective, in managing sheath blight of rice. The present investigation strongly supports the efficacy of Flusilazole in managing

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sheath blight with 100 percent inhibition.

5.6.2. Field experiment for the integrated management of sheath blight of rice

In present day agriculture, the scientists, farmers and general public all over the globe nurture the concept of managing the disease through environment-friendly methods, which consists of use of less chemicals and wider use of organics to avoid pollution and chemical residues in the ecosystem, thus promoting the organic farming approaches. Joining this trend, the present study had a strong mandate of exploring different management options for combating the sheath blight disease of rice. Based on the *in vitro* performance of the present study, the best treatments obtained from the new generation fungicides and liquid organic formulations were selected for conducting field experiment for the integrated management of sheath blight in rice.

The disease reaction was assessed by calculating Percent Disease Incidence (PDI) and Percent Disease Severity (PDS). Among the various treatments, the plots which were sprayed Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10) with PDI of 8.96 were most effective treatment in checking the disease and was on par with the standard fungicide Propiconazole 25 EC (0.1 %) with PDI of 7.76. The plots which were sprayed with Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (T9), and (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), Flusilazole 40 EC (0.15 %) (T3) and Vermicompost + Flusilazole 40 EC (0.15 %) (T8) ranked next with PDI of 10.07, 10.07, 10.13, 10.70, 11.17 and 12.08 respectively and were on par with each other.

The Per cent Disease Severity (PDS) varied from 9.66 to 60.23. Among the various treatments, the plots which were sprayed with Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10) ranked first with PDS of 9.66. This was followed by Propiconazole 25 EC (0.1 %) (T16) with PDS of 10.37) and Panchagavya 3% +

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(Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11 with PDS of 10.43), Flusilazole 40 EC (0.15 %) (T3 with PDS of 10.53), + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4 with PDS of 10.93), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9-11.43), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12-11.67), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13-12.50) and Vermicompost + Flusilazole 40 EC (0.15 %) (T8-14.60) in managing the disease and were significantly effective.

Growth parameters *viz.,* plant height, number of productive tillers/m^2 and yield attributes *viz.,* panicles/hill, number of spiklets/panicle, number of filled grain per panicle, thousand grain weight, grain and straw yield were calculated (Table 19). The treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Flusilazole 40 EC (0.15 %) (T3), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), EM 1% (T14), Panchagavya 3% (T1) was found to be highly effective increasing the plant height (Fig 3). The effect of different treatments on number of productive tillers was revealed that the treatments *viz.,* Panchagavya 3% (T1), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), were found to be highly effective in increasing the number of tillers with mean tiller number of 400.85, 406.0, 412.0 and 416.35 respectively.

The effect of different treatments on the number of panicles was revealed that the treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Propiconazole 25 EC (0.1 %) (T16), *Pseudomonas fluorescens* 2% (T15), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T9), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), were found highly effective in increasing the number of panicles with mean panicle numbers of 10.67, 10.33, 9.66, 9.33, 9.33 and 9.00 respectively. The effect

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of different treatments on number of spiklets per panicle showed that the plots which received the treatments *viz.,* Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Panchagavya 3% (T1), Vermicompost + Flusilazole 40 EC (0.15 %) (T8) were found significant in increasing the number of spiklets per panicle with mean spikelet numbers of 82.67, 80.67, 78.67, 76.33 and 76.33 respectively.

The effect of different treatments on number of filled grains per panicle revealed that the plots received with the treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC 0.15 %) (T10), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11) were superior in increasing the number of filled grains per panicle. They showed the mean of 61.00 and 60.00 respectively. The effect of different treatments on the thousand grain weight showed that the plots which received the treatments *viz.,* Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Propiconazole 25 EC (T16), (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T4), Panchagavya 3% (T1), EM 1% (T14), Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6) were found significantly superior in increasing the grain weight with the mean thousand grain weight of 29.97 , 29.33 , 28.47, 28.47, 28.33 and 28.10 g respectively.

The effect of treatments on grain yield revealed that the plots which received the treatment Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10) and Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T13) recorded significantly higher yields of 4189 kg/ha and 4183 kg/ha respectively. The treatments *viz.,* Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T6), Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) (T12), Vermicompost + Jeevamrutha 20% (T7), Panchagavya 3% (T1), Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11), Jeevamrutha 20% (T2) were found next in enhancing the yield of 4172, 4167, 4156, 4156, 4117 and 4112 kg/ha respectively. The plots which received the treatments *viz.,*

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Panchagavya 3% + Flusilazole 40 EC (0.15 %) (T10), Panchagavya 3% (T1) and Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) (T11) were found significantly superior over the treatments in increasing the straw yield of 7300, 7056 and 7033 kg/ha respectively.

B:C ratios were computed for each treatment by considering the total cost and returns. It was observed that the highest BC ratio of 1.61 was obtained with Panchagavya 3% + Flusilazole 40 EC at (0.15 %) (T10). This treatment also recorded the highest returns (94191Rs $ha^{-1)}$ followed by Panchagavya 3% (T1) which was obtained the B:C ratios of 1.59 and the treatments T7 (Vermicompost + Jeevamrutha 20%), T11 (Panchagavya 3% + Iprodione 25 WP + Carbendazim 25 WP(0.15 %) and T12 (Jeevamrutha 20% + Flusilazole 40 EC (0.15 %) were ranked next increasing the B:C ratios of 1.57. The control (T17) showed BC ratio of 1.11.

In conclusion, the beneficial effects of the liquid organic formulations and new generation fungicides were reflected significantly in reducing the disease incidence and severity of sheath blight in rice. Plant biometric characters *viz.,* plant height, number of productive tillers/m^2 and yield attributes *viz.,* panicles/ hill, number of spiklets/ panicle, number of filled grain per panicle, thousand grain weight, grain yield and straw yield had significantly increased due to the integrated applications of the liquid organics and new generation fungicides. The promising treatments for the integrated management of sheath blight were: (T10) Panchagavya 3% + Flusilazole 40 EC (0.15 %), (T16) Propiconazole 25 EC (0.1 %),(T9) Vermicompost + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %), (T13) Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) and (T11) Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %).

Studies conducted by various workers revealed that, liquid organic formulations *viz*., Panchagavya and Jeevamrutha had shown to improve plant resistance to various pests and diseases due to the activity of beneficial microbes present in these formulations and also acted as bio fertilizers, thus enhanced the

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yield of various crops (Natarajan, 2000; Solaiappan, 2002; Bhat *et al*., 2005; Tharmaraj *et al*., 2011). Xu (2001) reported that Effective Microorganism (EM) cultures present in these formulations could synthesize phytohormones *i.e.,* auxins and other growth regulators and also EM contained bioactive substances that could have significantly affected leaf stomata response.

In plant system, Flusilazole rapidly penetrates and eventually distributes through xylem vessels, thus protects new shoots from infection. Flusilazole selectively controls the pathogen infection by inhibiting the Ergosterol Biosynthesis (Itoh, 2000). Iprodione 25 WP + Carbendazim 25 WP is a combination product, having both systemic and contact action. It quickly absorbed by the green plant tissues and by roots. When it applied after infection, sporulation was suppressed and prevented the outbreak of the disease (Jacques, 1994). Bhuvaneswari and Raju, (2012) conducted field experiments at Maruteru A.P for sheath blight control and revealed that (Iprodione 25 WP + Carbendazim 25 WP) was one of the products which showed sheath blight incidence of 57.33%. The present investigation had shown that field level application of (Iprodione + Carbendazim) caused lesser Percent Disease Incidence (PDI) and Percent Disease Severity (PDS) of 10.70 and 10.93 respectively, which had strongly supported the efficacy of this new generation fungicide against sheath blight in rice.

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Summary

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6. SUMMARY

Sheath blight of rice caused by *Rhizoctonia solani* is a disease of great economic importance all over the rice growing countries in the world. Losses usually estimated have been to the tune of 50 per cent, depending on the extent of the severity of the disease and the stage at the crop is infected. Management of sheath blight poses challenges, since commercial varieties resistant to this disease are not available to the farmers. Among the traditional usual chemical and conventional methods, liquid organic formulations and new generation fungicides sound the best. Now a days, more emphasis is given to integrated disease management to combat plant diseases. The present investigation on 'Integrated disease management of sheath blight of rice' was carried out at the College of Horticulture, Vellanikkara. The salient findings of the study are summarized below:

6.1. A survey was conducted during August -September 2013 in ten rice growing locations of Thrissur district *viz*., Mannuthy, Chirakekode, Ollukkara, Vellanikkara, Pattikkad, Madakathara, Chalakudy, Adat, Pudurkara and Irinjalakuda. The occurrence sheath blight disease incidence was recorded in two farmer preferred popular varieties namely Uma (MO-16) and Jyothi (PTB-39). It was revealed that Per cent Disease Incidence (PDI) and Per cent Disease Severity (PDS) of sheath blight in ten rice growing locations of Thrissur district ranged from 24.53 to 51.95 and 44.76 to 85.53.

6.2. In the surveyed rice fields, it appeared initially as greenish grey, ellipsoid or ovoid, water soaked irregular lesions of one to three cm long. Centre of the spots were greyish white with brown margins. The symptoms were started near the water line and spread upwards. Sclerotia were formed on or near these lesions and were detached early. Irregular greenish grey lesions with brown margins were also observed on leaf lamina also. Under favourable condition, the disease spread very fast to adjacent tillers and caused death of whole plants.

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6.3. Characterization of sheath blight pathogen *R. solani* was observed on four different solid media *viz.,* Potato Dextrose Agar (PDA) medium, Czepck's Dox Agar (CDA) medium and Rose Bengal Agar (RBA) medium. Colony colour, growth pattern, sclerotial production and radial growth of pathogen showed great diversity in different solid media. *R. solani* on PDA showed abundant growth and mycelium on RBA showed moderate growth. In case of CDA and Richard's medium. They showed only slight growth. Growth rate was recorded at 24 h interval up to full growth observed in all plates. Growth rate of pathogen on PDA and RBA grew fast but on CDA and Richards's medium it was slow.

6.4. On the basis of the cultural and morphological characters, cluster analysis was done by using the UPGMA method. The isolates were grouped into two clusters A and B based on cultural characters. In cluster A, highest similarity coefficient of 0.69 was recorded between isolates ShMTY1, ShADT8 and ShOKRA3. Cluster A was further divided in to two sub clusters A1 and A2. In sub cluster A1, the highest similarity coefficient of 0.78 was recorded between isolates ShMTY1, ShADT8, ShOKRA3, ShIRJK10 and ShPTKA9, whereas lowest similarity index of 0.75 was recorded between isolates ShCKD2, ShVKA4 and ShPKD5 in sub cluster A2. Cluster B had no sub clusters and it showed the similarity index of 0.67 between the isolate of ShCKD2 and ShCKDY7.

6.5. Enumeration of microbial load from three liquid organic formulations at different storage period revealed that microbial profile of bacteria, and *Pseudomonas* spp. in all the three liquid formulations ranged from 93.66 - 95.0 and 88.0 –89.66 $\times 10^5$ cfu/ml respectively upto 120 days. At 210 days of storage, a slight decrease of bacterial population from 90.66 to 64.0 x 10^5 cfu/ml and increase in the number of fungal population from 34.0 to 42.0 $\times 10^4$ cfu/ml was noticed. So, these liquid organic formulations can safely be stored up to 120 days without loosing its viability.

6.6. Various liquid organic formulations *viz.,* Panchagavya, Dasagavya, and Jeevamrutha were tested *in vitro* and revealed that Jeevamrutha at 10 per cent

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concentration showed maximum inhibition of 85.18 per cent which was on par with Jeevamrutha 20% (79.62). Panchagavya at 3 and 2% ranked next with per cent inhibition of 80.73 and 76.29 respectively.

6.7. Among the different new generation fungicides Flusilazole 40 EC (0.15 %) and (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) showed 100 per cent inhibition of *R. solani*. Pencycuron 25 SC (0.15 %) ranked next with percent inhibition of 86.663 followed by Kresoxim methyl 44 SC (0.1 %) with per cent inhibition of 74.44.

6.8. The field studies under the present investigation have come out with an encouraging new array of management practices for combating sheath blight disease of rice in Kerala. The promising treatments to manage the disease were: Panchagavya 3% + Flusilazole 40 SC (0.15 %), Jeevamrutha 20% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %), Vermicompost + Jeevamrutha 20%, Panchagavya 3% and Panchagavya 3% + (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) in that order could be highlighted as promising treatments for managing the sheath blight disease of rice.

6.9. BC ratios were computed for each treatment by considering the total cost and returns. The highest BC ratio of 1.61 was obtained with Panchagavya 3% + Flusilazole 40 EC at (0.15 %). This treatment also recorded the highest returns (Rs. 94191Rs $ha^{-1)}$ followed by Panchagavya 3% which obtained the BC ratio of 1.59.

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Appendices

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APPENDIX I

MEDIA COMPOSITION

(Ingredients per litre)

Composition of different media used for various studies

Rose Bengal Agar medium

Dextrose	:	10.0 g
Peptone	:	5.0 g
KH_2PO_4	:	1.0 g
$MgSO_4$	:	0.5 g
Agar	:	20.0 g
Rose Bengal	:	0.03 g
Streptomycin	:	30.0 mg (added aseptically)
Distilled water	:	1000 ml

Ken Knight's Agar medium (pH 7.0)

Dextrose	:	1.0 g
KH_2PO_4	:	0.1 g
$NaNO_3$	:	0.1 g
KCl	:	0.1g
$MgSO_4$	:	0.1g
Agar	:	20.0 g
Distilled water	:	1000 ml

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Nutrient Agar medium

Peptone	:	5.0g
Beef extract	:	1.0g
Sodium Chloride	:	5.0g
Agar agar	:	20.0g
pH	:	6.5 to 7.

King's B medium

Peptone	: 20.0 g
Glycerol	: 10.0 ml
K_2HPO_4	: 10.0 g
$MgSO_4.7H_2O$	: 1.5 g
Agar agar	: 20.0 g
pH	: 7.2 – 7.4

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Abstract

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INTEGRATED MANAGEMENT OF SHEATH BLIGHT DISEASE OF RICE

By

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ABSTRACT OF THE THESIS

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For the degree of

Master of Science in Agriculture

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DEPARTMENT OF PLANT PATHOLOGY
COLLEGE OF HORTICULTURE
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ABSTRACT

Sheath blight of rice is a major threat to rice cultivation causing huge yield loss. Realizing the practical importance, an investigation entitled “Integrated management of sheath blight disease of rice” was carried out during 2013-2014 with the objective of developing an integrated management strategy for sheath blight using liquid organic formulations, vermicompost and selected new generation fungicides.

A series of surveys were conducted in ten locations of Thrissur district during *virippu* season of 2013 to study the occurrence of sheath blight in two farmer preferred popular varieties namely Uma (MO-16) and Jyothi (PTB-39). Per cent Disease Severity (PDS) was found to be maximum in paddy fields of Adat (85.53) and Chalakudy (84.30) followed by Pudurkara, Irinjalakuda and Mannuthy. Per cent Disease Incidence (PDI) and Per cent Disease Severity (PDS) of sheath blight in ten rice growing locations of Thrissur district ranged from 24.53 to 51.95 and 44.76 to 85.53 respectively.

Characterization of ten isolates of the pathogen (*Rhizoctonia solani*) was done on four different solid media *viz.,* Potato Dextrose Agar (PDA), Rose Bengal Agar (RBA), Czepck's Dox Agar (CDA) and Richard’s Agar (RA). Colony characters, sclerotial characters and growth rate of the ten isolates showed high diversity in different solid media. Based on these characters, cluster analysis was done by using the Unweighed Pair Group Average Method (UPGMA) isolates were grouped into two clusters A and B based on cultural characters. In cluster A, highest similarity coefficient of 0.69 was recorded. Cluster A was further divided in to two sub clusters A1 and A2. In sub cluster A1, the highest similarity coefficient of 0.78 was recorded. Cluster B had no sub clusters and it showed the similarity index of 0.67.

Enumeration of microbial load from three liquid organic formulations at different storage period revealed that microbial profile of bacteria, and *Pseudomonas*

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spp. in all the three liquid formulations ranged from 93.66 - 95.0 and 88.0 –89.66 × 10^5 cfu/ml respectively upto 120 days. At 210 days of storage, a slight decrease of bacterial population and increase in the number of fungal population from 34.0 to 42.0 × 10^4 cfu/ml was noticed. So, these liquid organic formulations can safely be stored up to 120 days without loosing its viability.

In vitro studies of various liquid organic formulations revealed that Jeevamrutha at 10 per cent concentration showed maximum inhibition of 85.18 per cent which was on par with Jeevamrutha 20% (79.62). Among the different new generation fungicides tested *in vitro*, Flusilazole 40 EC (0.15 %) and (Iprodione 25 WP + Carbendazim 25 WP) (0.15 %) showed 100 per cent inhibition against *R. solani.*

Based on the *in vitro* studies, field experiment were carried out and have come out with an encouraging new array of management practices for combating sheath blight of rice. The promising treatments to manage the disease were: (T10) Panchagavya 3% at 45 DAT + Flusilazole 40 EC (0.15%) at 60 DAT (T1) Panchagavya 3% at 45 & 60 DAT (T13) Jeevamrutha 20% at 45 DAT + (Iprodione25WP + Carbendazim 25WP) (0.15%) at 60 DAT (T7) Vermicompost @ 2.5 t/ha as basal +Jeevamrutha 20% at 45 & 60 DAT (T11) Panchagavya 3% at 45 DAT + (Iprodione 25 WP + Carbendazim 25 WP) (0.15%) at 60 DAT. These treatments gave high yield and net returns as evidence by the B:C ratios.

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