

**STUDIES ON BANDED LEAF AND SHEATH BLIGHT OF
MAIZE CAUSED BY *Rhizoctonia solani* f. sp. *sasakii*
EXNER**

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INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crop in terms of total production in the world. Maize is grown throughout the world under a wide range of climatic conditions. Maize was introduced to India from America at the beginning of 17th century. Maize is one of the important food, green forage and industrial crops of the world. It is called as queen of the cereals. Maize ranks third in the world after wheat and rice in area and production. Maize has highest productivity among the cereal crops.

Maize is widely cultivated throughout the world and a higher quantity of maize is produced each year than any other grain. While the United States and China produces almost half of the world's harvest, other top producing countries include Brazil, Mexico, Argentina, India and France. Worldwide production was around 852 mt in 174.2 m ha area during 2012, with a productivity of 4890.93 kg ha⁻¹. In India it is grown over an area of 8.67 m ha with total production of about 21.60 mt and productivity 2492 m ha. The major maize growing states that contributes more than 80% of the total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9 %), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1 %), Madhya Pradesh (5.7 %), Himachal Pradesh (4.4%). Hence, the maize has emerged as an important crop in the non-traditional regions *i.e.* peninsular India as the state like Andhra Pradesh which ranks 5th in area (0.79 m ha) has recorded highest production (4.14 mt) and productivity (5.26 t ha⁻¹) in the country. Which is much lower than most of the maize growing countries of the world. Karnataka is a one of the major maize producing states in the country. During 2011-12, a total area of 1.23 m ha of maize was grown with a production of 3.36 mt with an average productivity of 2721 kg ha⁻¹. (Anon., 2012).

Karnataka has six per cent of the total maize area with 16.5 per cent production share in the country. Nearly 90 per cent of the total production of maize comes from *Kharif*, which is the main growing season covering an area to the extent of 86 per cent. The irrigated ecosystem accounts for 60 per cent area and more than 90 per cent area is covered by hybrids. Under the irrigated ecosystem, it is cultivated throughout the year in command areas of Ghataprabha, Malaprabha, Tungabhadra and Upper Krishna projects. The major maize growing districts in Karnataka are Bagalkot, Belgaum, Bellary, Bijapur, Chitradurga, Davanagere, Dharwad, Gadag, Haveri, Koppal, Mysore and Shimoga. Among the cereals, maize is a wide spread crop and it is becoming very popular in hakkal upland paddy tract of malnad regions in Karnataka. It has great worldwide significance as human food, poultry feed, piggery feed and it has vast industrial potentialities having as many as 50 different uses. Maize can be used to the manufacture of starch, syrup, alcohol, acetic acid, lactic acid, glucose, paper, rayon, plastic, textiles, adhesives, dyes, synthetic rubber, resin, artificial leather, boot polish.

About 112 diseases of maize have been reported so far from different parts of the world. Of these, 65 are known to occur in India. The major diseases in different agro climatic regions are: seed rots and seedling blight, leaf spots and blights, downy mildews, stalk rots, banded leaf and sheath blight, and smuts and rusts, leading to about 15-20 percent yield losses annually (Saxena, 2002). Among them Banded Leaf and Sheath Blight (BLSB) of maize caused by *Rhizoctonia solani* f.sp. *sasakii* Exner (teleomorph:

Thanatephorus sasakii (Shirai) Tu & Kimbro), is gaining economic importance. It was reported for the first time from Sri Lanka by Bertus in 1927 under the name sclerotial disease (Bertus, 1927). Banded leaf and sheath blight was earlier reported as a minor disease on maize. Presently, the disease is considered as a major disease not only in India but also in several countries of tropical Asia wherever maize is grown. The disease was observed in the western central Himalayan foothill region of India in early sixties. The importance of the disease was only realized in early 1970's when an epidemic occurred in warm and humid foot hill areas in the Mandi district of Himachal Pradesh (Payak and Renfro, 1968).

Singh and Sharma (1976) estimated 40.5 per cent loss in grain yield with 71 per cent disease index. However, the magnitude of grain loss may reach as high as 100 per cent if the ear rot phase of the disease predominates. In India, losses in grain yield have been estimated in the range of 23.9 to 31.9 per cent in ten cultivars (Lal *et al.*, 1980). Payak and Sharma (1981) reported that annually around one per cent of the total grain yield is reduced by BLSB in India. Sharma *et al.* (2004) proved that banded leaf and sheath blight are major disease of maize and grain yield loss depends on disease severity which varies between 11-40 per cent.

The disease manifests on leaf, leaf sheaths, stalks and ears. The symptoms are leaf and sheath blight, stalk lesions or rind spotting and stalk breakage, clumping and cracking of styles (silk fibre), horse shoe shaped lesions with banding of caryopses, ear rots, etc. Under natural conditions, disease appeared at pre flowering stage on 30 to 40 day old plants but infection can also occur on young plants which may subsequently result in severe blighting and death of apical region of growing plants (Saxena, 2002). *Rhizoctonia solani* f.sp. *sasakii* does not produce spores and is generally identified by characteristics of the mycelium and sclerotia. Mycelium is colourless when young, but assumes a light brown colour as it matures. Under microscopic examination hyphae are multinucleate, hyaline, septate, and branch at right angles. Sclerotia are produced abundantly in culture and on infected plant parts. Sclerotia are typically 1 to 5 mm in diameter, spherical, and dark brown to black. The pathogen can survive in soil from several months to couple of year (Sneh *et al.*, 1991).

The crop is grown throughout the year in irrigated and rainfed condition in Karnataka. Until recently the crop was suffering from turicum leaf blight and common rust diseases. In recent year's banded leaf and sheath blight of maize caused by *Rhizoctonia solani* f.sp. *sasakii* was observed in several districts of Karnataka. It is necessary to conduct survey of the disease to get comprehensive information on disease distribution, level of severity, extent of spread and to locate hot spots for testing of genotypes in disease resistance screening programme.

Most of the composites and hybrids which are being grown on commercial scale are found to be more or less susceptible to BSLB. The reasons for lack of substantial durable resistance in the material may be attributed to presence of variability in the population (Zhang *et al.*, 2012). The problem of banded leaf and sheath blight disease of maize is increasing in this region thus characterization of pathogenicity of the newly emerging population is necessary to generate the information about the emergence of new pathotypes having adaptability to new traditional areas. In recent years, in Karnataka state also it was observe to succumb to banded leaf and sheath blight in several areas. This has led to speculation of possible occurrence of variation in the pathogen hence studies are required to know the possible existence of the variability in the growth and sclerotial formation among the various isolates from different parts of northern Karnataka.

In the absence of host resistance, many farmers are reliant on the use of systemic fungicides, biological control agents and botanicals for management of BSLB. Application of fungicide, biological control agents and botanicals is economically viable when susceptible varieties are grown and climatic conditions favour disease development. Treatment of the seed with fungicide prior to planting can reduce survival of the pathogen and reduce disease severity. Hence studies need to be under taken to assess the efficacy of various fungicides, biological control agents and botanicals *in vitro*. The information on disease management by using new effective fungicides, biological control agents and botanicals are unknown. Therefore it is necessary to test the field efficacy of some recently available new fungicides and seed dressers as seed treatment and foliar spray for the effective management of the disease. The magnitude of loss caused and importance of the disease, the present investigation on banded leaf and sheath blight of maize was undertaken with the following objectives.

1. Survey for the severity of disease.
2. Studies on variability in the pathogen.
3. *In vitro* efficacy of fungicides, botanicals and biocontrol agents.
4. Management of the disease.

REVIEW OF LITERATURE

The banded leaf and sheath blight caused by *Rhizoctonia solani* f.sp. *sasakii* Exner is an important disease on maize and it is sporadic in the maize growing areas of Karnataka. Literature available with respect to symptoms, distribution, disease development, chemical control and resistant source is limited. However information about the variability of the pathogen (morphological and cultural), sources for the growth of pathogen, chemical, botanical and biological control aspects are very meagre. Hence the present investigation aims to conduct systematic laboratory and field level studies on variability and management of banded leaf and sheath blight caused by *Rhizoctonia solani* f.sp. *sasakii* and the literature pertaining to these aspects are presented here under.

2.1 Symptomatology

Voorhees (1934) reported that under natural conditions, dropping of blades especially the distal halves of leaves proximate to soil surface were affected first. Infection spreads from leaf sheaths to the basal portion of leaves. Lesions appeared as irregular patches, brown in colour but larger in size and spread more rapidly than on leaf sheath, covering greater areas with alternating dark bands. Ahuja (1976) described symptom of BLSB as discontinuous lesions (5 to 10 cm in diameter) with dark brown margins and brown central areas on the leaf sheaths; they also caused ear rot. Sclerotia developed on the husks and sheaths were reddish or blackish brown, 1-5 mm in diameters, which is characteristic of BLSB of maize caused by *Rhizoctonia solani* f.sp. *sasakii*.

Saxena (1997) observed symptoms of the banded leaf and sheath blight on all aerial parts of maize plant except tassel. Under natural conditions, disease appeared at pre flowering stage on 30 to 40 days old plants but infection can also occur on young plants which may subsequently result in severe blighting and death of apical region of growing plants. Buddemeyer *et al.* (2004) observed round to elliptical, yellow to tan or black lesions on seminal, crown, and brace roots. Depending on disease severity, parts of the roots were completely rotten. Terminal decay was frequently observed in juvenile plants. A limited number of plants exhibited small medallion lesions on shoots.

2.2 Survey for the severity of disease

The disease was earlier reported as a minor disease on maize in India (Payak and Renfro 1966). The importance of the disease was only realized in early 1970s when an epidemic occurred in warm and humid foot hill areas in the Mandi district of Himachal Pradesh (Thakur *et al.*, 1973). Payak and Sharma (1981) reported occurrence of BLSB from Himachal Pradesh, Uttar Pradesh, Haryana, Punjab, Madhya Pradesh and Rajasthan. The disease was also reported from different parts of the world (Wiltshire, 1956; Von Eignatten, 1961 and Hirel *et al.*, 1988).

Sharma *et al.* (2002) reported that banded leaf and sheath blight caused by *Rhizoctonia solani* Kuhn was serious in recent years. During last two decades or so far the disease had continuous devastating advance, causing epidemic outbreak in maize growing country like Bhutan, China, India, Indonesia, Philippines, Vietnam and Nepal, as well as in several country of Africa and Latin America. The disease caused severe loss in several countries of Asia. Saxena (2002) identified Pantnagar as the endemic areas (hot spot) for BLSB disease in India.

Patra (2007) conducted survey on incidence of banded leaf and sheath blight diseases of maize during 2005-06 indicated that, disease intensity was moderate to severe on male inbred line CML-163 and female inbred line CML-193-1 of hybrid maize (HQPM-1) at pre-flowering stage in West Bengal. That was first report of BLSB from West Bengal.

Yang *et al.* (2008) surveyed during 2006 and revealed that banded leaf and sheath blight caused by *Rhizoctonia solani*, was showing wide spread with the disease severity ranging from 7.6 to 64.8 per cent and gaining the economic importance in the counties of Yunnan.

Akhtar *et al.* (2009) surveyed during *kharif* 2005-2006 and recorded occurrence of disease and diversity in *R. solani* among the naturally occurring populations and revealed that banded leaf and sheath blight caused by *Rhizoctonia solani* was showing wide spread with the disease severity ranging from 30.30 to 80.46 per cent and gaining the economic importance in the state of Jharkhand.

Karima *et al.* (2012) surveyed for tomato root rot disease caused by *R. solani* in Egypt. They recorded highest percentage of disease incidence in Quliobiya (12.5%), while the lowest one recorded in Giza (6.0%). In Ismaella and Fayoum, the percentages of root rot disease incidence were 7.5 and 8.0 per cent, respectively.

2.3 Studies on variability in the pathogen

R. solani was not produce spore and it was generally identified by characteristics of mycelium and sclerotial bodies. Mycelium was colourless when young, but assumes a light brown colour as it mature. Compound microscope studied revealed that *Rhizoctonia solani* characteristically having mycelium branching at right angles and septum near the branching junction. Hyphal width ranged from 4.75 μm to 7.43 μm (Hansen, 1963; Dhingra and Sinclair, 1973; Vijayan and Nair, 1985 and Sneh *et al.*, 1991).

Dhingra and Sinclair (1973) noticed variation in growth rate among the isolates from the same plant and between isolates from different plants on different media. Byadagi and Hegde (1985) grouped isolates of bean, *Cicer arietinum* and cowpea as virulent, sorghum and soybean isolates as intermediate and glyricidia isolate as mild, based on, morphology, cultural characters and pathogenic behaviour.

Arca and Yildizn (1989) reported that, out of 362 isolates of Aegean region, 333 exhibited variations in cultural characteristics, such as colony colour, mycelial growth, colony radius and the number of sclerotia. Groups of isolates were established based on radius and the number of sclerotia.

Than *et al.* (1991) conducted colony compatibility tests on 37 isolates of chickpea along with two isolates from different hosts, collected from different locations in Myanmar and reported the possible occurrence of more than one type of *R. bataticola* isolate in a field and the existence of closely related isolates at different places.

Meena *et al.* (2005) observed that eight isolates of *Rhizoctonia solani* f.sp. *sasakii* exhibited differences in colony characters, rate of mycelial growth and sclerotia production. All the isolates exhibited active anastomosis when paired on tap water agar indicating that these on susceptible maize cultivar Kiran. Shekhar *et al.* (2006) divided seven isolates into four groups on the basis of colony colour, i.e., greyish white, blackish gray, dark black in centre periphery cremish and cottony white colour.

Akhtar *et al.* (2009) collected five isolates from five different locations of Jharkhand, and showed variation in their morphological characters such as abundance of mycelium, colour and location, distribution, size and density of sclerotia etc. Pathogenicity revealed isolate Hc most aggressive while isolate Jr least aggressive.

2.3.1 Morphological studies

Haigh (1928) classified 27 strains of *R. bataticola* into three groups A, B and C, where C group included those strains having a mean sclerotial diameter of 120 μm or less, the B group included those with about 200 μm , while, A group comprised of sclerotia that could conveniently be measured in millimetres. Hildebrand *et al.* (1945) differentiated two strains of *R. bataticola* isolated from soybean (the Ontario strain), having mean sclerotial diameter of 90.4 x 75.8 μm on host plant and 99.9 x 89.4 μm in culture and from cotton (the texas strain) whose, sclerotia in culture averaged 85.4 x 73.0 μm and were produced in greater number.

Goidanich and Camici (1947) recorded sclerotial diameter of 65 to 75 μm on host and 100 to 115 μm in cultures with bean isolate and 115 to 135 μm on culture with broad bean isolates. Bean, egg plant, potato, chilli, tomato, bengalgram and pumpkin isolates produced smooth and round sclerotia, whereas those of cotton tobacco and sesame isolates were more or less irregular (Reichert and Hellinger, 1947). Similarly, studies with eight isolates revealed that the sclerotia of B4 and B43 was smaller, less compact and of irregular shape as compared with the other strains (Anon., 1955).

Dath (1985) reported that diameter of *Rhizoctonia solani* sclerotial ranged from 1 to 3 mm. Hao (1994) reported that sclerotial colour ranged from brown light to dark brown, black brown, chocolate brown, salmon and dark salmon. Size of sclerotial ranged from 0.85 to 3.05 mm.

Guleria *et al.* (2007) collected nineteen isolates of *Rhizoctonia solani* from different rice varieties grown in various regions of Punjab. They observed number of sclerotial per 5.0 mm culture disc of the test isolates ranged between 2.1 to 11.2 and their size varied between 1.31 and 2.08 mm. They observed brown colour sclerotial in all isolates, except two isolates which was dark brown and most of those were found scattered in the colony. Srinivas *et al.* (2007) collected ten isolates of *Rhizoctonia solani* f.sp. *sasakii* from major maize growing area of North India.

They showed morphological variability with respect to colour of colony (reddish brown to dark brown), pattern of sclerotial production (peripheral and scattered), weight of sclerotia (1.05 - 1.71 mg) and number of sclerotial production (10-20). Lal and Kandhari (2009) observed that *Rhizoctonia solani* was persistent problem to rice cultivation, and morphological variability was studied in 25 isolates from different rice growing areas. Colony size, colony colour, sclerotia formation (central, peripheral or scattered), location (aerial or surface) and texture (smooth or rough) varied in these isolated.

Goswami *et al.* (2010) collected 50 isolates of *Rhizoctonia solani* from soil of different agro-ecological zones of Bangladesh and also from infected plant parts of different crops and grasses. They classified all collected isolates into five different cluster groups on the basis of morphological and cultural characters. The lowest growth rate and the highest number of sclerotia were observed in cluster-I. The lowest zonation was observed in cluster III, which was followed by cluster I, V, and IV. The maximum zonation was found in cluster-II. The lowest duration of sclerotial initiation was observed in cluster III, which was followed by cluster-I, V, and II. The highest sclerotia initiation was found in cluster IV. Width of hyphae was the lowest in cluster-II, which was followed by III, IV & I and the highest in cluster-V.

2.3.2 Cultural studies

Uppal *et al.* (1936) reported variation in growth rate and colony character for two sorghum strains of *R. bataticola* from two different localities viz., Broach farm and Mohol farm in Maharashtra. Cultures of Broach strain showed concentric rings on PDA, while that of Mohol strain, produced aerial mycelium.

Khare *et al.* (1970) reported variability in growth pattern and rate of growth among six isolates from root, stem, pod, leaf and seeds of urd bean and soil, when grown on different media. Further they also observed that the soil isolate had the least amount of growth in almost all media while the pod isolate showed maximum growth.

Dhingra and Sinclair (1973) noticed variation in growth rate among the isolates from the same plant and between isolates from different soybean plants on different media. The stem isolates produced fluffy growth; root isolates showed partially fluffy growth and all other isolates produced appressed growth. Seed and petiole isolates produced concentric alternating zones of sclerotia and this character was more pronounced for the seed isolate. They also collected nine isolates of *R. bataticola* from various part of United States and reported variation in growth rate and colony characters. Anderson (1982) reported that the only character that clearly distinguished *Rhizoctonia solani* sclerotia, was their colour i.e. brown colour, reddish brown and dark brown colour.

Monga and Sheo (1994) collected 23 isolates of *Rhizoctonia solani* and 25 of *Rhizoctonia bataticola* from Punjab, Haryana and Rajasthan. They observed variation in the whitish mycelial growth on the surface of black mycelia mats and pigmentation was notice in different culture. Subramaniam (1994) collected eleven isolates of *Rhizoctonia bataticola* from different pulse crops. Based on morphological characters they were categorized into three groups viz., linear, fluffy, and linear at the end with fluffy growth at the centre. They also showed variability in sclerotial characters (intensity and shape) and intensity of pigment synthesis.

Tiwari and Khare (1998) collected 108 isolates of *R. solani* from diseased *Vigna radiata* samples collected from various locations in Madhya Pradesh. They were classified into 9 groups designated as I₁-I₉ based on morphological characteristics. They showed variation in their rate and type of growth, colony colour and time taken for sclerotial production *in vitro*. Sclerotia were not formed in I₃, I₆ and I₉. Isolate I₁ was binucleate while isolates I₂-I₉ were multinucleate.

Elewa *et al.* (2000) collected 53 isolates of *R. solani* from different host plants in 9 governates in Egypt All the tested isolates were multinucleate, and have brown pigmentation, lateral branching near the distal septum in young vegetative hyphae and septa formed at short distances from the origin of branches. *R. solani* was isolated on PDA from sheath blight-infected rice samples from different locations of West Bengal. Aerial growth was luxuriant to abundant in most isolates. It was moderate in R2 and sparse in R3. Growth was appressed in all the isolates and varied from woolly to cottony. Colony colour ranged from creamy to light brown (Basu *et al.*, 2004).

Yadav and Tiwari (2005) isolated 5 isolates of *R. solani* from diseased samples of fenugreek collected from different locations in Chattisgarh. Based on the morphological characters, the isolates were classified into 5 categories designated as I₁ to I₅.

All the isolates differed in the rate and type of growth, colony colour, hyphal width and sclerotial production. Isolate I₃ showed the highest growth on PDA medium and highest pathogenicity. Guleria *et al.* (2007) collected nineteen isolates of *Rhizoctonia solani* from different rice varieties grown in various regions of Punjab. They observed majority of the isolates were fast growing with raised and fluffy colonies and hyphal width of 9.6 μm while four exhibited moderate growth rate. Colony colour in all except two isolates was light yellowish brown.

Chowdary and Govindaiah (2007) reported that the radial growth was found maximum after 24 hours of incubation on PDA (40.3 mm), followed by Potato sucrose agar (39.0 mm), Czapeks dox agar (36.0 mm) and Oatmeal agar (35.5 mm). Likewise after 36 hr of incubation period also, the radial growth was found maximum on PDA (81.3 mm) followed by Czapeks dox agar (78.0 mm). After 48 hours of incubation, maximum radial growth of pathogen was recorded on Potato dextrose agar (90.0 mm) and minimum was noticed in Oatmeal agar (80.0 mm).

Thind and Rohit (2008) collected *R. solani* isolate from potato and rice field of Punjab. They observed maximum growth 20 mm colony per day in rice isolate compares to potato isolate 15mm colony per day. Colony growth of most of potato isolate was appraised, whereas that of most rice isolate was fluffy.

Jayaprakashvel and Mathivanan (2011) collected 236 *R. solani* isolates from 45 locations in the surveyed area in South India. Sclerotial features such as colour, size and shape and distribution pattern were varying among isolates.

2.4 *In vitro* efficacy of fungicides, botanicals and biocontrol agents.

2.4.1 Evaluation of fungicides

In vitro screening of fungicides reveal the efficacy of various fungicides and provide first hand information confirming fungi toxicity against specific pathogen and therefore it serves as a reliable basis for field testing. Several fungicides like Carbendazim, Bengard, Thiophenate Methyl, Iprobenfos, Captan, Quntozene, Mencozeb + Thiophenate Methyl, Copper oxychloride and Thiram are found to be effective in inhibiting the growth of pathogen in *in vitro* condition. Under field condition also, all the fungicides except Thiram were effective in reduce severity (Ahuja and Payak, 1986; Puzari *et al.*, 1998 and Sharma and Rai, 1999).

Jones *et al.* (1986) found 21 isolates of *Rhizoctonia solani* were sensitive to Benomyl @ 0.5 μg a.i. ml⁻¹ and Propiconazole @ 5.2 X 10⁻² μg a.i. ml⁻¹ under *in vitro* condition.

Kataria *et al.* (1991) reported that among 14 fungicides with different modes of action, Cyproconazole and Tolclofos-Methyl were generally inhibitory both *in vitro* and *in vivo* against 5 isolates of *Rhizoctonia spp.* Imazalil and Fenarimol showed moderate control, whereas Flusilazole, Propiconazole, Fenpropimorph and Benomyl showed strong activity against *R. zaeae* and *R. oryzae*, but were much less effective against *R. sasakii*, *R. cerealis* and *R. solani*. Benodanil and Iprodione controlled all isolates of *R. cerealis* and *R. solani* but were not very effective against *R. zaeae* and *R. oryzae*. Pencycuron showed strong activity against *R. sasakii* and most *R. solani* isolates, moderate activity against *R. zaeae* and was ineffective against *R. oryzae* and *R. cerealis*. Singh and Kaiser (1995) reported that, among the eight fungicides tested under *in vitro* and *in vivo* conditions, Bavistin was found most effective against *Rhizoctonia bataticola* in maize.

Kumar and Jha (2000) screened nine fungicides in the laboratory out of that Bavistin, Bengard and Topsin-M proved most effective as they caused the maximum inhibition of mycelial growth. Other fungicides *viz.*, Kitazin, Captaf, Brassicol, Indofil M-45 and Thiram also showed better performance regarding inhibition of mycelial growth of the pathogen in comparison to check. Abdulrahman (2005) reported that Benomyl inhibited the mycelial growth of *R. solani* by 94.4 per cent @ 12.5, 25 and 50 ppm.

Sundravadana *et al.* (2007) observed effect of Azoxystrobin on *R. solani* growth under *in vitro* condition and its efficacy against rice sheath blight, under field conditions. They observed Azoxystrobin at 1, 2, and 4 ppm, completely inhibited mycelial growth of *R. solani*. In field condition they showed that foliar spray of Azoxystrobin at 125, 250, and 500 g/ha significantly suppressed (> 64%) the development of sheath blight and enhanced yield level (> 60%).

Lehtonen *et al.* (2008) collected of 119 isolates of *Rhizoctonia* and tested for sensitivity to Flutolanil and for growth rate *in vitro*. In general, the isolates were rather sensitive to Flutolanil, the mean EC50 values ranging from 0.14 to 0.75 $\mu\text{g a.i. mL}^{-1}$.

Maniruzzman *et al.* (2010) evaluated fungicide response against *Rhizoctonia solani*. They found Carboxin was effectively inhibiting growth of *Rhizoctonia solani* at 100 ppm concentration. Mencozeb and boric acid at 100 ppm did not inhibit the growth of antagonist isolates of *Trichoderma harzianum* but inhibited the growth of isolate of *Rhizoctonia solani*.

Karima *et al.* (2012) found that the tested fungicides of Propamocarb 72.7 per cent, Hymexazol 30.0 per cent, Penocycuron 20 per cent, Flutolanil 25 per cent, Hymexazol 30 per cent and Topsin M 70 per cent significantly inhibited the mycelial growth of *R. solani* isolates at the concentrations of 12.5, 25, 50 and 75 ppm, respectively.

2.4.2 Evaluation of botanicals

Use of plant products in disease management is a recent eco-friendly approach and gaining popularity because of its advantages over chemicals. These plant extracts are easily biodegradable, do not leave any residue, non-phytotoxic and are easily absorbed by the plants and cost effective. The presence of naturally occurring substances in plants with antifungal properties have been reported and tested against wide range of fungi infecting many commercially important crops (Shivapuri *et al.*, 1997).

De Groot (1972) reported that inhibitory effect of plant products on the mycelial growth and sclerotial production of *Rhizoctonia solani* might be attributed to the presences of some antifungal ingredients *viz.*, diallyl disulphide and diallyl trisulphide in garlic and azadirachtin and monoterpenes in neem. Singh *et al.* (1980) reported that fruit pulp of *Azadirachta indica* suppress the formation of sclerotia of *Rhizoctonia solani* and inhibit growth of mycelium by 53.6 per cent. Dubey and Dwivedi (1991) reported that onion leaf extract at 5 per cent concentration check the growth of *Rhizoctonia bataticola* by 39 per cent.

Tavoularis *et al.* (1995) observed that total volatile substances from olive tree leaf compost fixed by silver nitrate solution (NH_3 and unsaturated hydrocarbons, etc.) inhibit the vegetative growth of *R. solani*. Kurucheve *et al.* (1997) studied on efficacy of thirteen plant extracts to screen *in vitro* against *Rhizoctonia solani* the causal agent of sheath blight of paddy. Out of these, the maximum inhibition of mycelial growth was observed in cold water extract of *Prosopis juliflora* followed by *Thevetia peruviana*. The complete inhibition of sclerotial production was recorded in cold water extract of *Caesalpinia pulcherrima*, *Eucalyptus globules* and *Lawsonia inermis* and in the hot water extract of *Calotropis gigantea*, *Ocimum sanctum* and *Prosopis juliflora* in 2.5, 5 and 10 per cent concentration.

Raja and Kurucheve (1998) reported that the extract of garlic bulb at 10 per cent inhibited the mycelia growth and sclerotial germination of *Rhizoctonia bataticola*. Meena *et al.* (2003) evaluated eight botanicals *in vitro* and *in vivo* against banded leaf and sheath blight of maize. They observed the increased efficacy of bulb extract of garlic when it was sprayed 24 hours before inoculation. The results revealed that, bulb extract of garlic (*Allium sativum*) at five per cent concentration completely inhibited mycelial growth of the fungus. It also reduced the per cent disease intensity in the field when applied to the foliage.

Abdulrahman (2005) studied antifungal activity of five plant extracts with either cold distilled water, boiling distilled water and cold ethanol. Highest mycelial growth inhibition of *R. solani* recorded in craway extracted with cold distilled (94.4 per cent) followed by garlic extracted with cold distilled (85.6 per cent). Sharma *et al.* (2005) studied on efficacy of eight plant extracts to screen *in vivo* and *in vitro* against *Rhizoctonia solani* f.sp. *sasakii*, the causal agent of banded leaf and sheath blight of maize. The maximum inhibition of mycelial growth and sclerotial production was observed in extract of *Allium sativum* at 10 per cent concentration.

Devchand *et al.* (2009) studied on efficacy of leaf extract of different medicinal plants and evaluated for their antifungal activity against *Rhizoctonia solani*. They observed the cold water extract of datura and neem showed significant reduction in mycelia growth by 70-79 per cent. Similar results on antifungal activity of aqueous extracts of different plants have been reported by (Ark and Thompson, 1959).

2.4.3 Evaluation of biocontrol agents

Vasantha Devi *et al.* (1989) observed degradation of sclerotia of *Rhizoctonia solani* by *Bacillus subtilis* bacterial antagonist by production of antibiotic like Inturin A and Surfactin. Although a hypovirulent strain of *Rhizoctonia solani* was investigated for its possibility in controlling *Rhizoctonia* disease of potato plants (Bandy and Tavantzis, 1990). Akihiro *et al.* (1993) reported that *B. subtilis* produced antifungal peptide antibiotic Inturin A and Surfactin which significantly inhibited mycelial growth of *R. solani*.

Saikia and Gandhi (1995) reported that *T. viride* was more effective than *T. harzianum* in reducing mycelial growth of *R. solani* causing cauliflower stem rot. Among nine isolate except for isolate T₉, all the isolates overgrew mycelial growth of *Rhizoctonia solani* by more than 50 per cent. Isolates T₂ and T₅ gave the highest degree of overgrowth of up to 89.1 per cent and 90.2 per cent, respectively. It was also found that isolate T₅ was least antagonistic to *Fusarium* and most antagonistic to *Rhizoctonia solani*. (Biswas, 1999). *T. viride* exhibited maximum growth inhibition of 33 per cent on *R. solani* when compared to *T. harzianum* which exhibited 29 per cent growth inhibition (Kumar and Dubey, 2001).

Moussa (2002) reported that *B. subtilis* has good potential for managing of *R. solani*. Sharma *et al.* (2002) reported that biocontrol agent, named *Trichoderma harzianum*, provided 68 per cent of mycelia inhibition of *R. solani* under *in vitro* conditions compared to the control of BLSB.

Meena *et al.* (2003) reported that *Trichoderma harzianum* was effective in causing significances suppression of both, growth and sclerotial formation of *Rhizoctonia solani* f.sp. *sasakii*. *Trichoderma harzianum* cause 80 per cent inhibition of mycelial growth after 72 h of incubation and 35.5 per cent inhibition of sclerotial formation after 10 days of incubation followed by *Trichoderma viride*.

Vaish and Sinha (2006) reported that thirteen isolates of *Gliocladium spp.* and four isolates of *Aspergillus niger* obtained from different sources *viz.*, soil, rice rhizosphere, rice leaves and rice leaf sheath were evaluated for their biocontrol ability against *R. solani*, the causal agent of sheath blight of rice. Four isolates of *Gliocladium spp.* and four isolates of *Aspergillus niger* were found effective in dual culture. Four isolates of *Gliocladium sp.* attained mycelial growth of 90.00 mm after 120 hrs and 3 isolates attained mycelia growth of 90.00 mm after 144 hrs. In case of co-culture with *R. solani*, *A. niger* attained a growth of 30.00 to 34.67 mm after 144 hrs. Two isolates of *Gliocladium spp.* and all four isolates of *A. Niger* were found highly inhibitory to the mycelial growth of the pathogen by producing volatile substances.

Biswas *et al.* (2008) evaluated bio control agents and one botanical *viz.*, *Trichoderma harzianum*, *T. viride*, *Pseudomonas fluorescens*, garlic extract and Achook against brown spot and sheath blight pathogen *in vitro* and also as seed dresser. In dual culture test they reported that, *Trichoderma harzianum* was reduced maximum mycelia growth by 42.7 per cent.

Sharma *et al.* (2009) reported that *Trichoderma atroviride* II inhibited maximum mycelial growth by 79.9 per cent followed by *Trichoderma harzianum* III 65.5 per cent. Twelve isolate of *Trichoderma* belonging to three different species were evaluated for their antagonistic activity against *Rhizoctonia solani* infected rice. All *Trichoderma* isolate in dual culture inhibited mycelial growth of *Rhizoctonia solani* significantly and inhibition ranged from 89.5 to 62.5 per cent. *Trichoderma harzianum* showed maximum inhibition of mycelial growth by 89.5 per cent whereas *Trichoderma aureoviride* showed the minimum inhibition of 62.5 per cent (Agrawal and Kotasthane, 2010).

All the five strains tested were exhibited antagonistic activity against *R. solani*. One isolate, *Pseudomonas fluorescens* 003 gave 78 per cent inhibition compared to control. (Reddy *et al.*, 2010).

Seema and Devaki (2012) studied on efficacy of four fungal and one bacterial bio agents in *in vitro* condition against the tobacco sore shin pathogen, *Rhizoctonia solani* and observed percentage inhibition of growth of *Rhizoctonia solani* by *T. viride*, *T. harzianum*, *A. niger*, *B. subtilis* and *Penicillium spp.* were 70 per cent, 67 per cent, 57 per cent, 50 per cent and 44 per cent respectively.

2.5 Management of the disease

There is little information on integrated management of banded leaf and sheath blight of maize. Hence it is necessary to study the possibility of managing this disease by combining seed treatment with foliar application of bioagents or fungicides.

Jones *et al.* (1986) applied Propiconazole twice or Propiconazole followed by Benomyl that significantly reduced the severity of sheath blight of rice and increase yield. They observed that Propiconazole followed by Propiconazole or Propiconazole followed by Benomyl was economically feasible when more than 5 per cent diseased tiller were observed at panicle differentiation growth stage of rice. They obtained maximum yield 1229 Kg ha⁻¹ when Propiconazole @ 0.11 kg a.i. ha⁻¹ at panicle differentiation and 0.11 kg a.i. ha⁻¹ at boating stage. Formulations of antibiotic Validamycin also show good control against BLSB on maize (Jiang *et al.*, 1991).

Puzari *et al.* (1998) studied the efficacy of one antibiotic and six fungitoxicant *viz.*, Validamycin (0.1%), Carbendazim (0.1%), Captan (0.25 %), Hexaconazole (0.1%), Telcofos Methyl (0.2 %), Mancozeb (0.3 %) and Chlorothalonil (0.15%). They were tested against banded leaf and sheath blight of maize caused by *Rhizoctonia solani* f.sp. *sasakii*. They found Validamycin (0.1%) followed by Carbendazim (0.1 %) performed best in managing the disease.

Saxena (2002) tested efficacy of chemicals (*viz.*, Propiconazole, 0.1%, and Carbendazim, 0.05%), by applying as foliar sprays at 30, 40 and 50 days of planting, alone or in combinations. They observed effectiveness of Propiconazole when the chemical was applied at initial stages at 30 or 40 day after planting and the second spray at 10 days after first. They showed foliar sprays of Carbendazim less effective against BLSB of maize.

Seed treatment and soil application of this antagonist not only reduces the disease to more than 50 per cent, but additionally increase in grain yield approximately 1.4 times of the yield of the control (Sharma *et al.*, 2002).

Several microorganisms are known to parasitize *Rhizoctonia* species. Such as fungal species *viz.* *Trichoderma*, *Gliocladium*, and *Laetisaria*, bacteria (*Pseudomonas fluorescens*), and nematodes (*Aphelenchus avenae*). Reduction in disease incident of BLSB of maize was observed when *P. fluorescens* was used in seed and soil treatment and in foliar application (Meena *et al.*, 2003).

Khan and Sinha (2006) evaluate the effect of integration of organic amendments and fungal antagonist on sheath blight on rice. The maximum reduction in disease severity and incidence were recorded with FYM + *Trichoderma harzianum*. Kapoor *et al.* (2006) observed significant difference among the different integration levels, amendments with *Lantana camara* + bioagent Trichogourd @ 2.5 kg FYM /ha + spray with Carbendazim at pre flowering stage was most effective in managing the root rot wilt complex disease in pea.

Rajbir Singh and Sinha (2007) evaluated field efficacy of foliar applications of different formulations of a bacterial bioagents *P. fluorescens* (Pfr1 and Pfr 5) at three rates *viz.*, 2, 4 and 8 g/l against sheath blight of rice. The result indicates that the disease severity was significantly reduced by foliar application of strain Pfr 1@ 8 g/l of water.

Sivakumar and Sharma (2007) reported that BLSB was effectively managing by seed treatment with the peat based formulation @ 16 g/kg or soil application @ 2.5 kg/ha or spraying the liquid formulation twice @ 5 g/l of water on maize foliage. They observed seed treatment with *P. fluorescens* increased population of fluorescent *Pseudomonas* in the rhizosphere. Soil application of *P. fluorescens* along with seed treatment resulted in further increase in rhizosphere population of the bacterium in glass house and field conditions.

Akhtar *et al.* (2011) studied bio-assay of fungicides against *Rhizoctonia solani* showed and reported that Carbendazim inhibited 93.8 per cent growth even at the concentration of 5 ppm. Under field conditions, Carbendazim (0.2 %) proved most effective as seed treatment showing 68.00 per cent reduction in disease over control and as a foliar spray (0.1%), it resulted least disease severity (25.78 %) and highest grain yield (31.50 q/ha). Singh and Singh (2011) conducted field trial by using cultural practices, bioagents and fungicide. They observed that minimum disease intensity was 1.36 per cent on 1–5 scale and maximum yield 42.28 q/ha in case of foliar spray of Validamycin @ 0.25 per cent followed by Propiconazole @0.1 per cent and Carbendazim @0.1 per cent for BLSB of maize. Foliar spray of Mencozeb @0.25 per cent was found to be least effective among all chemicals, but showed significantly lower disease severity and higher grain yield over check.

Bunker *et al.* (2012) reported that seed treatment with *Trichoderma harzianum* followed by spray application with Carbendazim @ 0.1 per cent were more effective than seed treatment alone against BLSB of maize. The maximum grain yield (52.0 q ha⁻¹) with significantly reduced disease (46.8 %) and increased grain yield (51.6 %) were recorded in the seed treatment with *Trichoderma harzianum* followed by spray application with Carbendazim @ 0.1 per cent.

MATERIAL AND METHODS

The present investigation on banded leaf and sheath blight of maize, caused by *Rhizoctonia solani* f.sp. *sasakii* was carried out during 2012 at Main Agriculture Research Station, Saidapur farm, Dharwad and Dept. of Plant Pathology, Agricultural College, University of Agricultural Sciences, Dharwad. During the research, lab studies were conducted at Dept. of Plant Pathology, Agricultural College, University of Agricultural Sciences, Dharwad and field experiments were conducted at Main Agriculture Research Station, Saidapur farm, University of Agricultural Sciences, Dharwad. The details of material and methods used during the course of investigation are given below.

3.1 General procedure

3.1.1 Glassware and Cleaning

In all the experiments Borosil and corning glasswares were used. Petriplates of 90 mm diameter were used for isolation purpose and cultural studies. Conical flasks of 500 and 250 ml were used for preparation of various media. The glasswares were kept in a cleaning solution containing 60 g potassium dichromate ($K_2Cr_2O_6$) and 60 ml of concentrated sulphuric acid (H_2SO_4) in one litre of water for 24 hours and afterwards they were washed in running water and cleaned with Vim powder. After rinsing twice in distilled water, they were air dried.

3.1.2 Sterilization

All glasswares were sterilized in autoclave at 15 lb pressure for 20 min and the media were sterilized at 15 lb pressure for 15 min.

3.1.3 Collection of diseased samples

The diseased leaves and leave sheaths of maize plants of showing characteristic symptoms of banded leaf and sheath blight were collected from six locations of Northern Karnataka during the survey programme. All six diseased samples were collected for the purpose of variability study.

3.1.4 Identification of the fungus

In order to confirm the identity of the fungus the mycelium was observed under the high power (40X) microscope from the fresh leaves and leave sheaths of the infected maize plant. Observations such as branched at right angle to main hyphae, slightly constricted at the junction and cross wall near the junction were recorded by using compound microscope and they were compared with original description of the fungus. Sclerotia were observed from naked eyes.

3.1.5 Isolation of the pathogen

Collected infected leaves and leave sheaths were used for isolation. Infected portion of leaves and leave sheaths were cut into small pieces of 5 to 6 mm and the bits were surface sterilized with 1:1000 (0.1%) sodium hypochlorite solution for one min. followed by three times wash with sterile distilled water and then transferred to Petriplates containing sterilized potato dextrose agar (PDA). These plates were incubated at $26 \pm 1^\circ C$ for four days to obtain good growth of fungus.

The principle growth characters like morphological, cultural and formation of sclerotia were considered for identification of pure cultures of *Rhizoctonia solani* f.sp. *sasakii*. These characters were compared as described by Bertus (1927) and Saxena (2002) and identified as *Rhizoctonia solani* f.sp. *sasakii* depending on the observed traits.

3.1.6 Maintenance of the culture

The pure cultures of the fungus were sub-cultured on potato dextrose agar slants and kept in laboratory at $28 \pm 2^\circ C$ for 15 days. Such mother culture slants were preserved at $5^\circ C$ in refrigerator. Further, these cultures were sub-cultured once in a month and used for future studies.

3.2 Survey for the severity of banded leaf and sheath blight of maize

To assess the extent of banded leaf and sheath blight disease severity, intensive roving survey was conducted during *Kharif* 2012 in major maize growing districts of Northern Karnataka. In each district important maize growing talukas were selected, in each village five fields were randomly selected on both sides of road when the crop was in flowering to grain filling stage. Such fields were assessed for banded leaf and sheath blight severity by recording the disease on 1-5 disease ratings scale (Ahuja and Payak, 1983).

The details of the scale are given as follows:

Scale	Description
1	Disease on one leaf sheath only, few small, non coalescent lesions present.
2	Disease up to four leaf sheaths, lesions many, large and coalescent.
3	Disease on all leaf sheaths, except two internodes below the ear, rind discolored with small lesions.
4	Disease up to internodes bearing the shoot but shank not affected, rind discolored with large lesion, abundant fungal growth between and on kernels, ear size is less than normal, some plants premature dead, shrinkage of stalk, reduced ear dimensions.
5	Disease on the ear, husk and leaves show bleaching, wet rot disorganization of ear, kernel formation absent or rudimentary, prematurely dead of plants is common, abundant sclerotial production on husk, leaves, kernels, ear tips and silk fibers.

Further PDI was calculated by using the following formula (Wheeler, 1969).

Percent Disease Index =	Sum of individual disease ratings	x 100
	Total no. of plants observed x Maximum grade	

Based on severity, the disease incidence was categorised as follows.

0 – 5%	: Slight (traces)
5.1 – 15%	: Light
15.1 – 30%	: Moderate
30.1 – 65%	: Severe
> 65%	: Very severe

3.3 Studies on variability of the pathogen

The banded leaf and sheath blight infected leaves and leaf sheaths sample were collected from different parts of Northern Karnataka during survey programme and pure cultures of six isolates were maintained on PDA. Morphological and cultural characters were carried out in laboratory. The details of six isolates are furnished below.

Isolate	Place of origin
Rsm1	Dharwad
Rsm2	Rannebennur
Rsm3	Gokak
Rsm4	Haveri
Rsm5	Mundgod
Rsm6	Kalaghtagi

3.3.1 Morphological studies

Sclerotia of *Rhizoctonia solani* f.sp. *sasakii* were observed from pure cultures of different isolates maintained on PDA and number, size, shape, time taken for initiations of sclerotial formation, pattern of production and colour were recorded. Further photo micrographs were taken to show the typical mycelia morphology of the fungus.

3.3.2 Cultural studies

Twenty ml of each of the potato dextrose agar was poured separately into Petriplates. Each isolate was replicated thrice. With the use of 4 mm cork borer a 15 days old culture was taken and inoculated. Such plates were incubated at incubated at 28 ± 2 °C temperatures for 4 day.

The growth characters of the fungus colony diameter, colour of colony and growth pattern were studied on potato dextrose agar. The colony diameter was recorded by averaging the radial growth of the colony in two directions for each plate of the fungus. The data on radial growth were also analyzed statistically.

3.4 *In-vitro* evaluation of fungicides, botanicals and bio agents.

3.4.1 Evaluation of fungicides

Poison food technique was followed to test the efficacy of the fungicides. The pathogen *Rhizoctonia solani* f.sp. *sasakii* was grown on PDA medium in Petriplates for four days prior to experiment. Fungicide suspension was prepared in PDA by adding requisite quantities of fungicides to obtain the desired concentration on the basis of active ingredient of the chemical. Poisoned medium was poured in each of the sterilized Petriplates. Mycelial disc of 4 mm was taken from the periphery of the four days old culture and placed in the centre and incubated at 28 ±2 °C till growth of the fungus reaches the periphery in the control plate. Three replications were maintained for each treatment. The colony diameter was measured in two directions and average was worked out. The per cent of inhibition of growth was calculated by using the formula (Vincent, 1947).

$$I = 100(C-T) / C$$

Where, I = Per cent inhibition of mycelium growth

C = Growth of mycelium in control

T = Growth of mycelium in treatment

Treatment details

Six systemic fungicides viz., Propiconazole 25 EC, Hexaconazole 5 EC, Difenconazole 25 EC, Thiophenate-M 60 WP, Carbendazim 50 WP and Tebuconazole 250 EC were evaluated *in vitro* at 0.025, 0.05 and 0.1 per cent concentration and four non systemic fungicides viz., Mancozeb 75 WP, Copper oxychloride 50 WP, Zineb 68 WP and Chlorothalonil 65 WP were evaluated *in vitro* at 0.1, 0.15 and 0.2 per cent concentration. In addition six combi product fungicides viz., Carbendazim 12%+ Mancozeb 63%, Carboxin 36.5% + Thiram 36.5%, Tricyclozole 18% + Mancozeb 62%, Hexaconazole 4% + Zineb 68%, Carbendazim 25% + Iprodion 25% and Trifloxystrobin 25%+ Tebucanazole 50% were evaluated *in vitro* at 0.1, 0.15 and 0.2 per cent concentration. Antibiotic Validamycin screened at 0.03, 0.04 and 0.05 per cent concentration below this list of all the fungicides and mention their chemical names and trade name in a tabular format.

Common name	Trade name
Systemic fungicides	
Propiconazole 25 EC	Tilt
Hexaconazole 5 EC	Contaf
Difenconazole 25 EC	Folicure
Thiophenate - M 60 WP	Topsin M
Carbendazim 50 WP	Bavistin 50WP
Tebuconazole 250 EC	Score
Non systemic fungicides	
Mancozeb 75 WP	Indofil M 45
Copper oxychloride 50 WP	Blue copper
Zineb 68 WP	Dithane Z-7
Chlorothalonil 65 WP	Kavach
Combi product fungicides	
Carbendazim 12%+ Mancozeb 63%	Saaf
Carboxin 36.5% + Thiram 36.5%	Vitavax power
Tricyclozole 18% + Mancozeb 62%	Avtar
Hexaconazole 4% + Zineb 68%	Merger
Carbendazim 25% + Iprodion 25%	Quintol
Trifloxystrobin 25%+ Tebucanazole 50%	Nativo
Antibiotic	
Validamycin	Validamycin

3.4.2 Efficacy of botanicals.

Plant based pesticides are relatively cheaper, safe and non-hazardous and they can be used easily and successfully against the plant pathogenic fungi.

The present investigation was aimed to study the antifungal activity of some plant extracts. The following plant extracts were evaluated at 5 and 10 per cent concentration

Botanical	Common name	Plant part used
<i>Azadirachta indica</i>	Neem	Oil
<i>Azadirachta indica</i>	Neem	NSKE (SEED)
<i>Jatropha curcas</i>	Jatropha	Leaf
<i>Annona raticulata</i>	Custard apple	Seed
<i>Curcuma longa</i>	Turmeric	Leaf
<i>Allium cepa</i>	Onion bulb	Bulb
<i>Pongomia pinnata</i>	Karanza leaf	Leaf
<i>Datura stremonium</i>	Datura seed	Seed

Preparation of plant extract

Fresh plant part of each test plant were collected and washed with tap water and then in distilled water. Then 100 grams of fresh sample was crushed in a surface sterilized pestle and mortar by adding 100 ml sterile distilled water (1:1 w/v). The extracts were filtered through two layers of muslin cloth. Finally filtrate, thus obtained, was used as a stock solution. To study the anti-fungal mechanism of plant extract the poisoned food technique was followed as suggested by Sharma *et al.* (2005). Five and ten ml of stock solution was mixed with 95 and 90 ml of sterilized molten PDA media respectively so as to get 5 and 10 per cent concentration. The medium was thoroughly shaken for uniform mixing of the extract.

Twenty ml of poisoned medium was poured into Petri plate and 4 mm diameter of culture disc from actively growing fungus was kept at the centre of each Petri plate. Three replications were maintained for each treatment and the plates were incubated at $25 \pm 1^\circ \text{C}$. Suitable control was maintained by growing the culture on PDA without the botanicals. The radial growth of colony was recorded when maximum growth was observed in control plate and per cent inhibition was calculated by using the formula given by Vincent (1947).

$$I = 100(C-T) / C$$

Where,

I = Per cent inhibition of mycelium growth

C = Growth of mycelium in control

T = Growth of mycelium in treatment

3.4.3 Efficacy of biocontrol agents.

In vitro antagonistic activity of *Trichoderma harzianum*, *Trichoderma viridie*, *Trichoderma koningi* and *Trichoderma virens* against *Rhizoctonia solani* f.sp. *sasakii* was carried out by dual culture method as described by Seema and Devaki (2012). Petridish containing 20 ml of sterile PDA was inoculated with 4 mm diameter plug of 4 days old pure culture of antagonistic fungi and pathogen. One mycelia disc of each fungus was placed on opposite pole of PDA plate and incubated at $28 \pm 2^\circ \text{C}$ in incubator. In case of *Bacillus subtilis* and *Pseudomonas fluorescens* parallel streaking was done on one side of the agar plate and incubated at $36 \pm 2^\circ \text{C}$ for 24 hrs. After the incubation period 4 mm diameter mycelia plug of actively growing *Rhizoctonia solani* f.sp. *sasakii* was placed on opposite pole and incubated at $28 \pm 2^\circ \text{C}$ for 4 days. Three replications were maintained for each treatment. The colony diameter was measured in two directions and average was worked out. The per cent of inhibition of growth was calculated by using the formula (Vincent, 1947)

$$I = 100(C-T) / C$$

Where,

I = Per cent inhibition of mycelium growth

C = Growth of mycelium in control

T = Growth of mycelium in treatment

Five bioagents were tested against *Rhizoctonia solani* f.sp. *sasakii*. List of antagonists used in the study along with their source are presented below

Antagonist	Source
<i>Trichoderma viride</i> Pers.ex. Fr.	Dept. of Plant Pathology, UAS, Dharwad
<i>Trichoderma harzianum</i> Rifai	Dept. of Plant Pathology, UAS, Dharwad
<i>Trichoderma virens</i> Miller	Dept. of Plant Pathology, UAS, Dharwad
<i>Trichoderma koningi</i> Oudem	Dept. of Plant Pathology, UAS, Dharwad
<i>Pseudomonas fluorescens</i> Migula	Dept. of Agril. Microbiology, UAS, Dharwad
<i>Bacillus subtilis</i> (Ehrenberg) Cohn	Dept. of Agril. Microbiology , UAS, Dharwad

3.5 Management of the disease

The field trail was conducted during *Kharif* 2012 at Main Agriculture Research Station, Saidapur farm, Dharwad in a split plot design with three replications. The field trail was conducted under irrigated, red soil conditions. Hybrid DKC- 8101 was sown on 10th June, 2012 in a plot size 3 x 3 m with spacing of 60 x 20 cm in 6 rows. Recommended dose of fertilizers and insect control measures were followed.

3.5.1 Treatment detail

Main plots : Seed treatment

Sl. No.	Seed treatment	Dosage
S1	<i>Pseudomonas fluorescens</i>	10 g/kg
S2	<i>Trichoderma harzianum</i>	10 g/kg
S3	Tebuconazole 50 WG	1.5 g/kg
S4	Untreated Control	-
S5	Carboxin 36.5% + Thiram 36.5%	2.5 g/kg
S6	Carbendazim 50 WP	3.25 g/kg
S7	Mencozeb 50% + Carbendazim 25%	2.5 g/kg

Sub plots: Foliar Sprays

Sl. N.	Foliar Spray	Dosages
F1	Difenconazole 25 EC	1 ml/l
F2	Tebuconazole 250 EC	1 ml/l
F3	Hexaconazole 5 EC	1 ml/l
F4	Propiconazole 25 EC	1ml/l
F5	Untreated control	-
F6	Carbendazim 50 WP	1g/l
F7	<i>Pseudomonas fluorescens</i>	10g/l
F8	Mancozeb 65 WP	3g/l
F9	Carbendazim 12%+ Mancozeb 63%	2g/l
F10	Carboxin 36.5% + Thiram 36.5%	2g/l
F11	<i>Trichoderma harzianum</i>	10g/l
F12	Hexaconazole 4% + Zineb 68%	2g/l
F13	Tricyclozole 18% + Mancozeb 62%	2g/l
F14	Trifloxystrobin 25% + Tebuconazole 50%	1g/l

Foliar sprays were given at 30 and 40 days after sowing. Observations on disease severity were recorded using 1-5 scale at silk drying stage and the per cent disease index was calculated. The 100 seed weight, grain yield and stover yield and per cent disease control over control data were recorded on maturity and analysed statistically.

EXPERIMENTAL RESULTS

The experiments on banded leaf and sheath blight of maize caused by *Rhizoctonia solani* f.sp. *sasakii* were conducted in the Department of Plant Pathology, College of Agricultural, University of Agricultural Sciences, Dharwad and Main Agricultural Research Station, Saidapur farm, University of Agricultural Sciences Dharwad . The results obtained are presented here under.

4.1 Symptomatology

Banded leaf and sheath blight symptoms were characterized by concentric bands and rings on infected leaves and leaf sheaths that are discolored, brown, tan or grey in colour. Typically, disease developed on the first and second leaf sheath above the ground and eventually spread to the ear causing ear rot. Ear rot were characterized by light brown, cottony mycelium on the ear and the presence of small, round, black sclerotia. Ear dried prematurely and caking of the ear sheaths was notice. Mycelium was colorless when young, but assumes a light brown color as it matured. Under microscopic examination hyphae were multinucleate, hyaline, septate, and branch at right angles. Sclerotia were produced abundantly in culture and on infected plant parts. Sclerotia were typically 1 to 5 mm in diameter, spherical and dark brown to black. The symptoms are presented in Plate1.

4.2 Isolation

Isolation of the fungus was done following standard isolation procedure as described in material and methods. Thus obtained pure culture was multiplied for further studies. The fungus was sub cultured on potato dextrose agar slants and stored in a refrigerator for further studies, the original culture was sub cultured once in month.

4.3 Disease survey

Survey was carried out during *kharif* 2012 in major maize growing areas of Northern Karnataka by adopting roving survey methodology as mentioned in material and methods. The mean per cent disease severity data recorded at various locations is presented in Table1 and depicted in Fig 1.

The disease survey revealed that banded leaf and sheath blight disease was sporadic in major maize growing areas of the North Karnataka in low to severe form with the severity ranging from 10.75 per cent to 52.45 per cent. The mean per cent disease severity was worked out in percentage. Among the four districts surveyed, maximum disease severity was observed in Uttarkannada district (51.10%), followed by Haveri district (34.30%) and the lowest disease severity (17.73%) in Belgaum district. The highest BSLB severity was observed in Kalaghatagi taluka of Dharwad district (52.45%) followed by Mundgoad taluka of Uttarkannada district (51.54%), Haveri taluka of Haveri (43.25%) and Ranebennur taluka of Haveri (41.65%). Lowest incidence was noticed in Bailhongal taluka of Belgaum district (10.75%) followed by Soudatti taluka of Belgaum district (12.57%). The highest BSLB severity was observed in red soil of Kalaghatagi followed by black soil of Mundgoad taluka whereas least severity observes in black soil of Bailhongal. Highest severity observed in red soil followed by black soil. The highest severity observed in irrigated condition whereas lower severity observed in rainfed condition. DKC8101 hybrid recorded highest disease severity whereas 900M recorded lowest disease severity. Maturity stage recorded highest disease severity on CP818 whereas knee height stage recorded lowest on 900M.

4.4 Morphological and cultural variability in the pathogen

4.4.1 Morphological variability

Morphological features of six isolates of *Rhizoctonia solani* f.sp. *sasakii* were observed by growing the isolates on PDA medium. Different parameters like sclerotia size, shape, days taken for sclerotial formation, number of sclerotia, pattern of sclerotia production and colour of sclerotial were considered to assess the possible variation among isolates. The data on morphological variability is mentioned in Table 2 and Plates 2 and 3.

4.4.1.1 Size of sclerotia

The size of sclerotia varied from 1.87 mm to 3.1 mm. It was observed that the Rsm6 isolate produced largest sclerotia of 3.1 mm, followed by Rsm5 (2.5 mm) and Rsm3 (1.98 mm) while the smallest size sclerotia of 1.87 mm was produced by Rsm4.



Initial symptom with large, discoloured areas alternating with irregular dark bands on leaf and leaf sheath



Ear rotting



Sclerotial production on stem

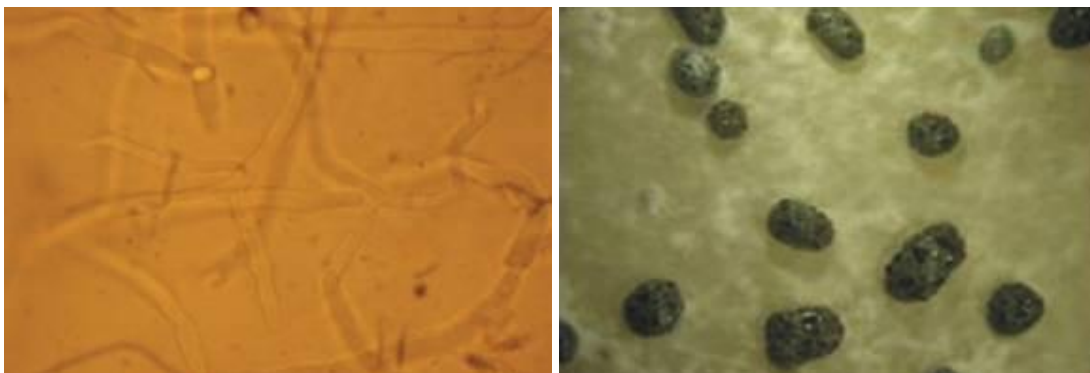
Plate 1. Symptom of banded leaf and sheath blight

Table 1. Severity of banded leaf and sheath blight in major maize growing areas of Northern Karnataka during *Kharif* 2012

District	Taluk	Location	Soil type	Rainfed/ irrigated	Hybrid	Stage of crop during survey	PDI (1-5 scale)
Dharwad	Dharwad	Dharwad	Black	Rainfed	CP818	Maturity stage	29.75
	Kalaghtagi	Kalaghtagi	Red	Irrigated	DKC8101	Maturity stage	52.45
	Hubli	Hubli	Black	Rainfed	900M	Harvesting stage	15.72
						Average	32.64
Belgaum	Bailhongal	Bailhongal	Black	Irrigated	CP818	Knee height stage	10.75
	Soudatti	Soudatti	Black	Irrigated	900M	Knee height stage	12.57
	Gokak	Gokak	Black	Irrigated	DKC8101	Maturity stage	29.87
						Average	17.73
Haveri	Haveri	Haveri	Black	Irrigated	CP818	Flowering stage	43.25
	Haveri	Shiggon	Black	Rainfed	DKC8101	Flowering stage	31.50
	Haveri	Savanoor	Black	Rainfed	900M	Knee height stage	20.81
	Ranebennur	Halgeri	Black	Irrigated	DKC8101	Flowering stage	41.65
						Average	34.30
Uttarkannada	Mundgod	Mundgoad	Red	Rainfed	DKC8101	Maturity stage	51.54
	Mundgod	Pala	Red	Rainfed	CP818	Maturity stage	50.67
						Average	51.10



Fig. 1: Severity of banded leaf and sheath blight in major maize growing areas of Northern Karnataka during *kharif* 2012



Mycelium at 400 X

Magnified view of Sclerotial body

Plate 2. Mycelium and sclerotial body of *Rhizoctonia solani* f. sp. *sasakii*

4.4.1.2 Shape of sclerotia

Round shape sclerotial bodies observed in Rsm1, Rsm2, Rsm3 and Rsm4 isolates and oval shape observed in Rsm5 and Rsm6.

4.4.1.3 Days taken for sclerotial body formation

Most of the isolates took ten days for production of sclerotia, except Rsm3 and Rsm4 isolates, which took fifteen days for sclerotial formation. Rsm6 took eight days for sclerotial production.

4.4.1.4 Number of sclerotia per plate

Maximum number of sclerotia observed in Rsm6 (115) followed by Rsm5 (105). Minimum sclerotia produced by Rsm3 (54) followed by Rsm1 (80) in 90 mm Petriplates.

4.4.1.5 Pattern of production

Maximum isolates produced sclerotial body in peripheral circular manner, except Rsm1 and Rsm4 which produced irregular in manner.

4.4.1.6 Colour of sclerotia

Rsm1 and Rsm2, Rsm5 produced brown colour sclerotia, Rsm3 and Rsm6 dark brown colour. Rsm4 produced red brown colour.

4.4.2 Cultural variability

Cultural characters such as colony character, colony diameter, mycelium width and dry mycelium weight of six isolates of *Rhizoctonia solani* f.sp. *sasakii* were studied. Details of the characters of these six isolates, designated as Rsm1 to Rsm6 are mentioned in Table 2. All the six isolates showed considerable variability with respect to colony characters, colony diameter, mycelium width and dry mycelium weight.

4.4.2.1 Colony character

Growth of isolates viz., Rsm5 and Rsm6 was excellent and isolates Rsm2 Rsm4 good growth, Rsm1 produced moderate growth, whereas poor growth was observed in Rsm3 isolate.

4.4.2.2 Colony diameter

Maximum radial growth was observed in the isolates Rsm5 and Rsm6 with colony diameter of 90.00 mm followed by Rsm4 (86.40 mm) and Rsm2 (86.00 mm). Moderate colony diameter was observed in Rsm1 (82.50 mm). Minimum colony diameter noticed in Rsm3 (79.33 mm).

4.4.2.3 Mycelium width

Maximum mycelium width was observed in Rsm5 (7.13µm) followed by Rsm6 (6.94 µm) and Rsm4 (6.83 µm). Minimum mycelium width was observed in Rsm3 isolate (5.35 µm).

4.4.2.4 Dry mycelium weight

Maximum dry mycelium weight was observed in Rsm6 (565.00 mg) followed by Rsm5 (532.00 mg), Rsm4 (494.00 mg) and Rsm1 (489.00 mg). Minimum dry mycelium weight was observed in Rsm3 (206.00 mg). Based on the varying levels of growth the isolates were categorised into the following four groups.

Sl. No.	Group	Isolate
1.	Excellent growth	Rsm5 and Rsm6
2.	Good growth	Rsm4 and Rsm2
3.	Moderate growth	Rsm1
4.	Poor growth	Rsm3

4.5 *In vitro* Evaluation of fungicides, botanicals and bioagents

4.5.1 *In vitro* evaluation of fungicides against *Rhizoctonia solani* f.sp. *sasakii*

Efficacy of six systemic, four nonsystemic, six combiproduct fungicides and one antibiotic were tested at different concentrations by poison food technique as explained in material and methods.

The per cent inhibition of the growth of the test fungus at different concentration over control was calculated. The results pertaining to the effect of fungicides on inhibition of *Rhizoctonia solani* f.sp. *sasakii* are presented in Table 3, 4 and 5, Figs. 2, 3 and 4, and Plates 4 and 5.

Results revealed that all the test fungicides significantly inhibited mycelial growth of the fungus. Among the six systemic fungicides tested, Propiconazole 25% EC (100%) and Carbendazim 50% WP (100%) gave maximum mean mycelial inhibition which were significantly superior to all other treatments followed by Hexaconazole 5% EC (98.03%) and Tebuconazole 250% EC (95.28%).

At 0.025 per cent concentration, Propiconazole 25% EC and Carbendazim 50% WP (100% and 100% mycelial inhibition respectively) were statistically on par with each other as well as significantly superior over remaining fungicides followed by Hexaconazole 5% EC with mycelia inhibition 94.11%. Whereas Tebuconazole 250% EC (91.75%), Difenconazole 25% EC (91.75%) and Thiophenate-M 70 WP (91.75%) were statistically on par to each other.

At 0.05 per cent concentration, significantly maximum mean per cent inhibition of mycelial growth was recorded in Propiconazole 25% EC and found to be effective (100% mycelial inhibition) which was statistically on par with Hexaconazole 5% EC (100%) and Carbendazim 50%WP (100%) and was significantly differ with Thiophenate-M 70 WP (94.11%), Tebuconazole 250% EC (94.11%) and Difenconazole 25% (94.11%) EC.

All systemic fungicides showed 100 per cent inhibition at 0.01 per cent. Among five systemic fungicides tested Propiconazole 25% EC, Carbendazim 50%WP and Hexaconazole 5% EC were found to be most effective at all concentrations whereas Tebuconazole 250% EC, Difenconazole 25% EC and Thiophenate- M 70 WP were found least effective at lower concentrations.

Carbendazim 12%+ Mancozeb 63% and Carbendazim 25% + Iprodion 25% at 0.1 per cent gave 100% inhibition and were found to be the most effective fungicides and similar trend was observed in the treatment with Carbendazim 12% + Mancozeb 63% and Carbendazim 25% + Iprodion 25% at 0.1, 0.15 per cent and 0.2 per cent (100%). Least inhibition of mycelial growth was observed in Tricyclozole 18% + Mancozeb 62% at 0.1 per cent (28.11%).

Carbendazim 12%+ Mancozeb 63%, Carbendazim 25% + Iprodion 25%, Carboxin 37.5% + Thiram 37.5% and Trifloxystrobin 25% + Tebuconazole 50% @ 0.15 per cent concentration which gave 100% inhibition. Least inhibition of mycelial growth was observed in Tricyclozole 18% + Mancozeb 62% (45.11%).

Carbendazim 12%+ Mancozeb 63%, Carbendazim 25% + Iprodion 25%, Carboxin 37.5% + Thiram 37.5% and Trifloxystrobin 25% + Tebuconazole 50% @ 0.2 per cent concentration were found to be most effective and gave 100 per cent mycelial inhibition of fungus which is statistically on par with each other. Least inhibition of mycelial growth was observed in Tricyclozole 18% + Mancozeb 62% (45.11%).

Among the combiproduct fungicides tested, Carbendazim 12%+ Mancozeb 63% and Carbendazim 25% + Iprodion 25% were found to be most effective at all concentrations. Tricyclozole 18% + Mancozeb 62% were found to be least effective.

Among four non systemic fungicides and one antibiotic tested Mancozeb 75 WP (94.07%) and Validamycin (88.33%) gave maximum mean mycelial inhibition which were significantly superior to all other treatments followed by Chlorothalonil 75 WP (83.88%) and Zineb 78 WP (82.40%). Least mean mycelial inhibition observed in Copper oxychloride 50 WP (73.70%).

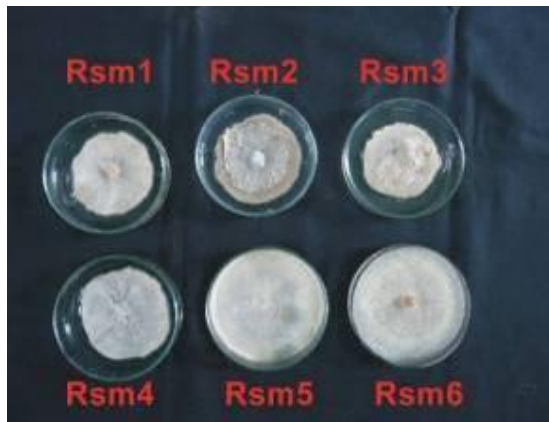
At 0.1 per cent concentration Mancozeb 75 WP gave maximum mean mycelial inhibition 88.88 per cent which was significantly superior over other fungicides followed by Chlorothalonil 75 WP (80.55%) and Validamycin (80.55%). Least inhibition of mycelial growth was observed in Copper oxychloride 50 WP (57.77%).

Mancozeb 75 WP @ 0.15 per cent concentration gave maximum mean mycelial inhibition 95.55 per cent which was significantly superior over other fungicides, followed by Validamycin (88.88%) and Chlorothalonil 75 WP (82.22%). Least inhibition of mycelial growth was observed in Copper oxychloride 50 WP (74.44%).

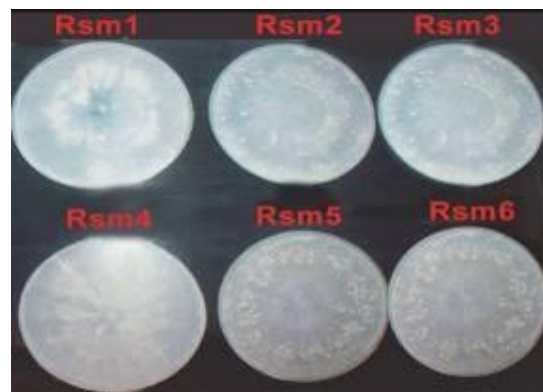
At 0.2 per cent concentration Mancozeb 75 WP gave maximum mean mycelial inhibition 97.77 per cent which was on par with Validamycin (95.55%). Least inhibition of mycelial growth was observed in Copper oxychloride 50 WP (82.22%).

Table 2. Cultural and morphological variability in the isolates of *Rhizoctonia solani* f. sp. *Sasakii*

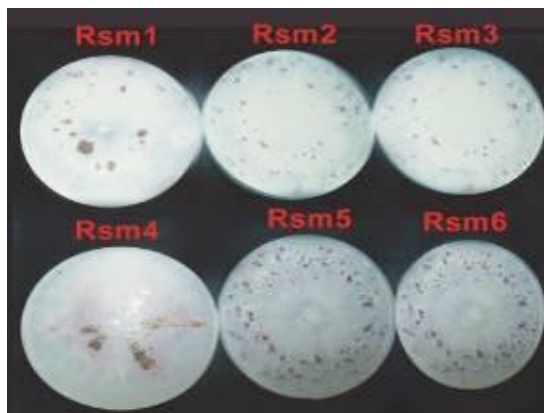
Location	Isolate	Colony Character	Colony diameter (mm)	Hyphal width (Avg. μm)	Dry weight of mycelium (mg)	Sclerotia I diameter (mm)	Shape of sclerotia	Days taken for sclerotia I body formation	Number of sclerotia/plate	Pattern of production	Colour of sclerotia
Dharwad	Rsm1	White colour moderate growth	82.50	5.94	489.00	2.45	Round	10	80	Irregular	Brown
Ranebennur	Rsm2	White colour good growth	86.00	6.81	348.00	2.40	Round	10	86	Peripheral circular	Brown
Gokak	Rsm3	White colour slow growth	79.33	5.35	206.00	1.98	Round	15	54	Peripheral circular	Dark brown
Haveri	Rsm4	White colour good growth	86.40	6.83	494.00	1.87	Round	15	92	Irregular	Red brown
Mundgod	Rsm5	White colour Excellent growth	90.00	7.13	532.00	2.5	Oval	10	105	Peripheral circular	Brown
Kalaghtagi	Rsm6	White colour Excellent growth	90.00	6.94	565.00	3.1	Oval	8	107	Peripheral circular	Dark brown



Four days after incubation



Initiation of sclerotial body



Mature culture with sclerotial body

Plate 3. Photograph showing growth of different isolates on potato dextrose agar (PDA)

Table 3. *In vitro* evaluation of systemic fungicides against *Rhizoctonia solani* f. sp. *sasakii*

Fungicide	Per cent inhibition of mycelial growth			Mean
	Concentration (%)			
	0.025	0.05	0.1	
Hexaconazole 5 EC	94.11 (75.99)	100.00 (90.05)	100.00 (90.05)	98.03 (81.97)*
Propiconazole 25 EC	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)
Difenconazole 25 EC	91.75 (73.35)	94.11 (75.99)	100.00 (90.05)	95.28 (77.49)
Thiophenate- M 70 WP	91.75 (73.35)	94.11 (75.99)	100.00 (90.05)	95.28 (77.49)
Carbendazim 50 WP	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)
Tebuconazole 250 EC	91.75 (73.35)	94.11 (75.99)	100.00 (90.05)	95.28 (77.49)
Mean	94.89 (76.97)	97.06 (80.17)	100.00 (90.05)	
	Fungicide (F)	Concentration (C)	F X C	
S. Em ±	0.74	0.64	1.36	
C.D.at 1%	3.03	2.62	5.57	

*Figures in the parentheses indicate arc sine transformed values

Table 4. *In vitro* evaluation of combi product fungicides against *Rhizoctonia solani* f. sp. *sasakii*

Fungicide	Per cent inhibition of mycelial growth			Mean
	Concentration (%)			
	0.1	0.15	0.2	
Carbendazim 12 % + Mancozeb 63 %	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)*
Carboxin 37.5 % + Thiram 37.5 %	99.33 (85.35)	100.00 (90.05)	100.00 (90.05)	99.78 (88.75)
Tricyclozole 18 % + Mancozeb 62 %	28.11 (31.80)	45.11 (41.83)	45.11 (41.83)	39.44 (38.49)
Hexaconazole 4 % +Zineb 68 %	55.07 (47.55)	68.80 (56.07)	75.60 (60.43)	66.49 (54.68)
Carbendazim 25 % + Iprodion 25 %	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)	100.00 (90.05)
Trifloxystrobin 25 % + Tebuconazole 50%	99.67 (86.75)	100.00 (90.05)	100.00 (90.05)	99.89 (88.95)
Mean	80.36 (71.92)	85.54 (76.35)	86.67 (77.07)	84.19 (75.11)
	Fungicide (F)	Concentration (C)	F X C	
S.Em ±	0.87	0.72	1.70	
C.D.at 1%	3.57	2.95	6.97	

*Figures in the parentheses indicate arc sine transformed values

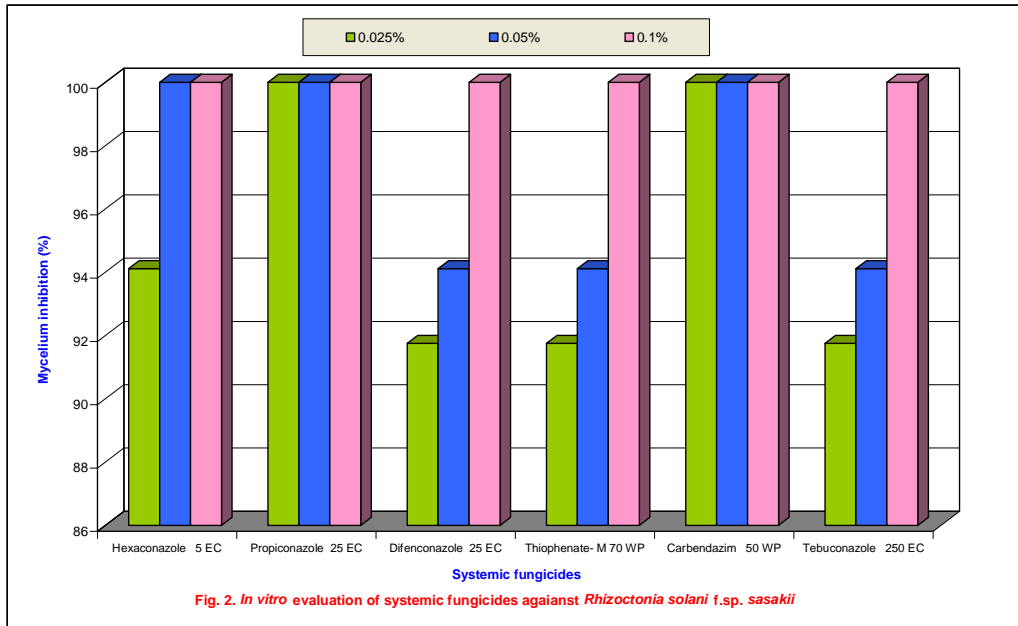


Fig. 2. In vitro evaluation of systemic fungicides against *Rhizoctonia solani* f.sp. sasakii

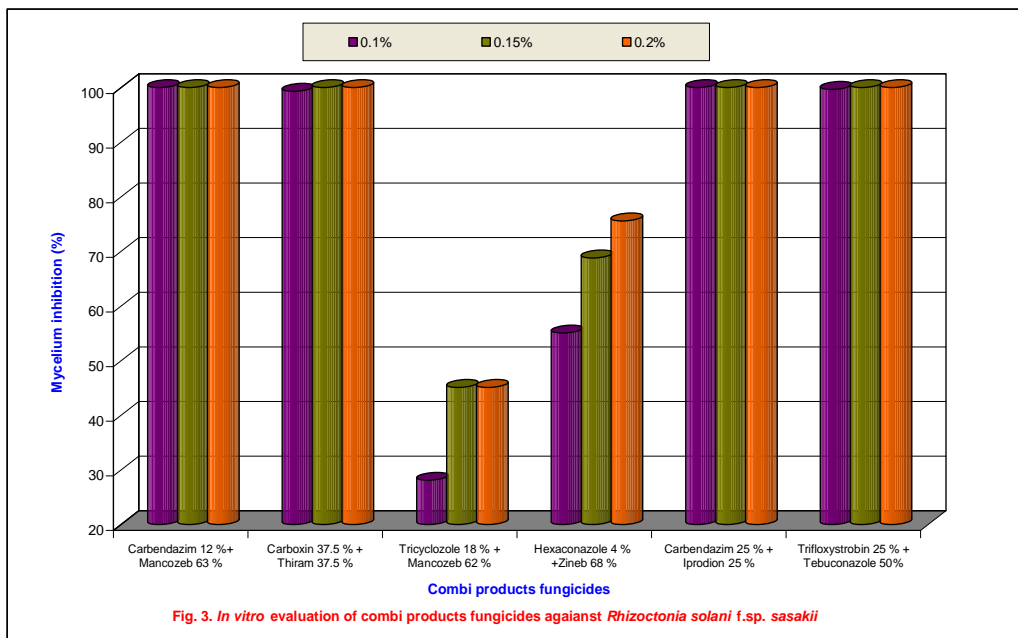


Fig. 3. In vitro evaluation of combi products fungicides against *Rhizoctonia solani* f.sp. sasakii

Table 5. *In vitro* evaluation of contact fungicides and antibiotic against *Rhizoctonia solani* f. *sp. sasakii*

Fungicide	Per cent inhibition of mycelial growth			Mean
	Concentration (%)			
	0.1	0.15	0.2	
Chlorothalonil 75 WP	80.55 (63.86)	82.22 (65.09)	88.88 (70.56)	83.88 (66.36)*
Zineb 78 WP	77.77 (61.85)	80.55 (63.86)	88.88 (70.56)	82.40 (65.23)
Copper oxychloride 50 WP	57.77 (49.50)	74.44 (59.66)	82.22 (65.86)	73.70 (59.18)
Mancozeb 75 WP	88.88 (70.56)	95.55 (77.86)	97.77 (81.45)	94.07 (75.94)
Mean	76.24 (60.89)	83.19 (66.43)	89.43 (71.60)	
	Fungicide (F)	Concentration (C)	F X C	
S. Em ±	0.89	0.69	1.50	
C.D.at 1%	3.49	2.71	6.05	
Antibiotics				
	0.03	0.04	0.05	
Validamycin	80.55 (63.86)	88.88 (70.56)	95.55 (77.86)	88.33 (70.06)

*Figures in the parentheses indicate arc sine transformed values

Table 6. *In vitro* evaluation of botanicals against *Rhizoctonia solani* f. *sp. sasakii*

Botanicals	Per cent inhibition of mycelial growth		Mean
	Concentration (%)		
	5	10	
<i>Azadirachta indica</i> (Nimicidine)	46.67 (43.11)*	51.11 (45.66)	48.89 (44.39)
<i>Azadirachta indica</i> (NSKE)	43.33 (41.19)	46.87 (43.11)	45.12 (42.15)
<i>Jatropha curcas</i>	32.22 (34.6)	40.00 (39.25)	35.56 (36.62)
<i>Annona raticulata</i>	20.02 (26.58)	27.78 (31.82)	23.89 (29.27)
<i>Curcuma longa</i>	22.22 (28.14)	38.89 (38.6)	31.11 (33.92)
<i>Allium cepa</i>	35.56 (36.62)	44.64 (41.83)	40.21 (39.25)
<i>Pongomia pinnata</i>	33.33 (35.28)	43.33 (41.19)	38.33 (38.27)
<i>Datura stremonium</i>	41.18 (40.55)	47.78 (43.75)	45.00 (42.15)
Mean	34.44 (35.96)	38.47 (38.35)	
	Botanical (B)	Concentration (C)	B X C
S.Em ±	0.81	0.72	1.45
C.D.at 1%	2.41	2.15	4.32

Figures in the parentheses indicate arc sine transformed values

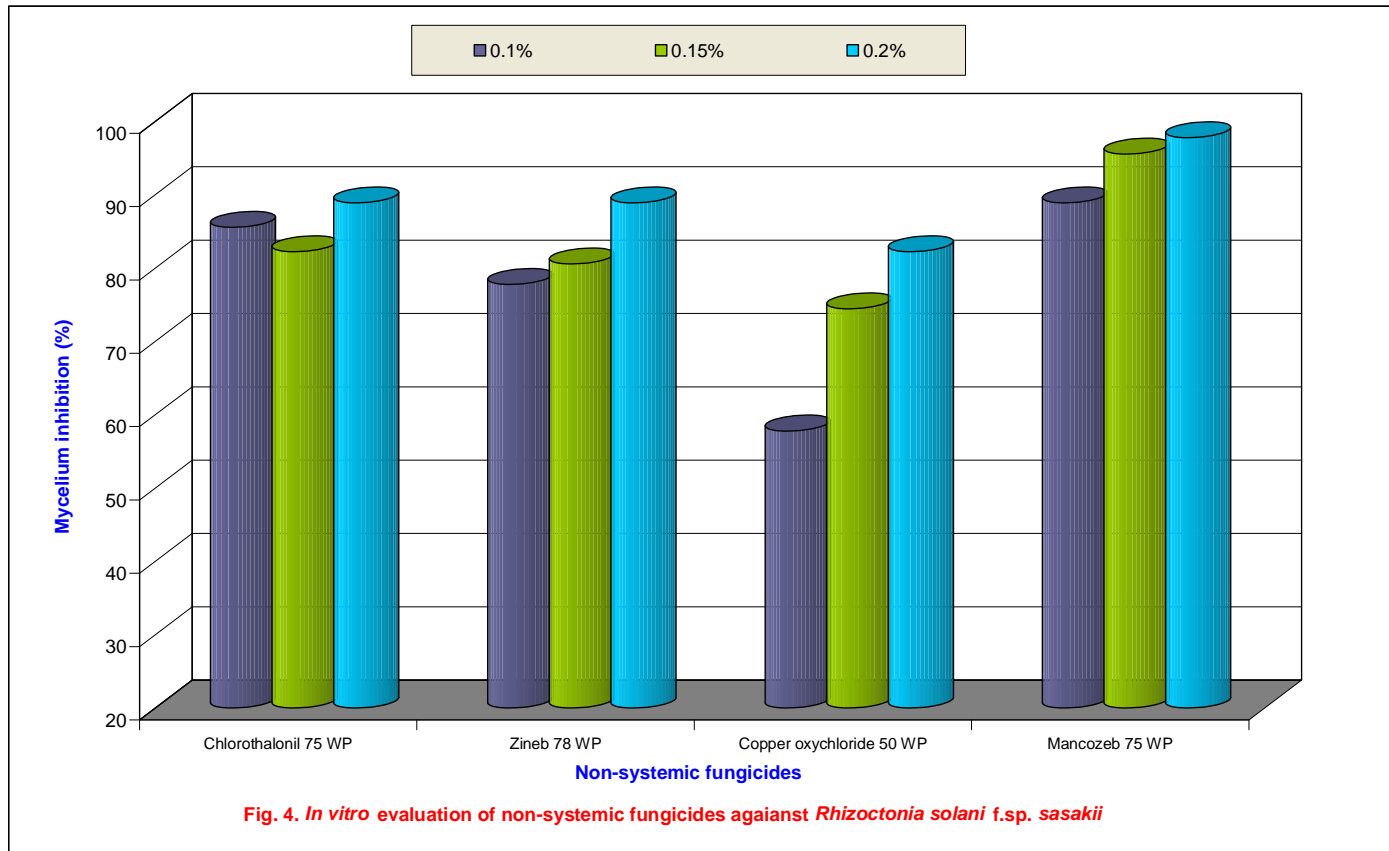
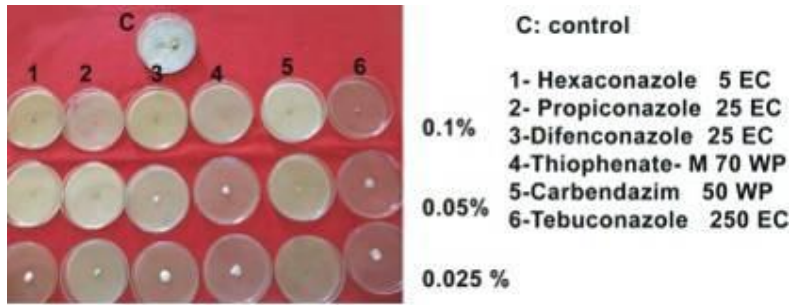
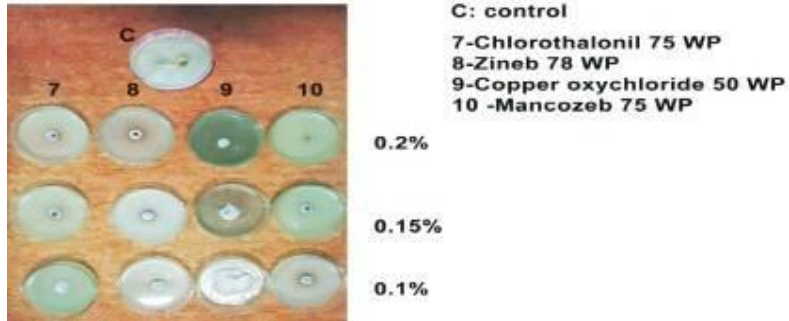


Fig. 4. In vitro evaluation of non-systemic fungicides against *Rhizoctonia solani* f.sp. sasakii



Systemic fungicides



Non Systemic fungicides

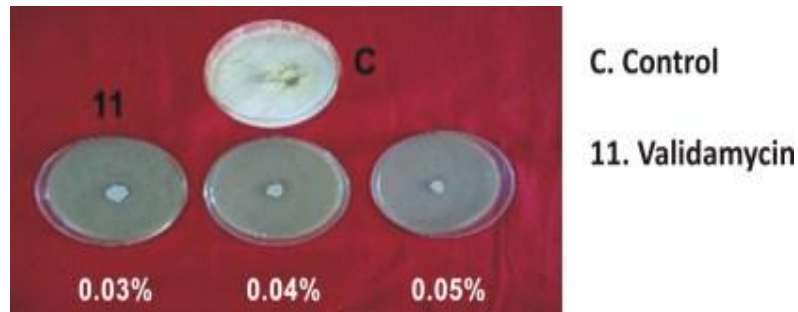


Plate : *In vitro* evaluation of fungicides against *Rhizoctonia solani* f. sp. *sasakii*



Plate 5: *In vitro* evaluation of combi product fungicides *Rhizoctonia solani* f. sp. *sasakii*

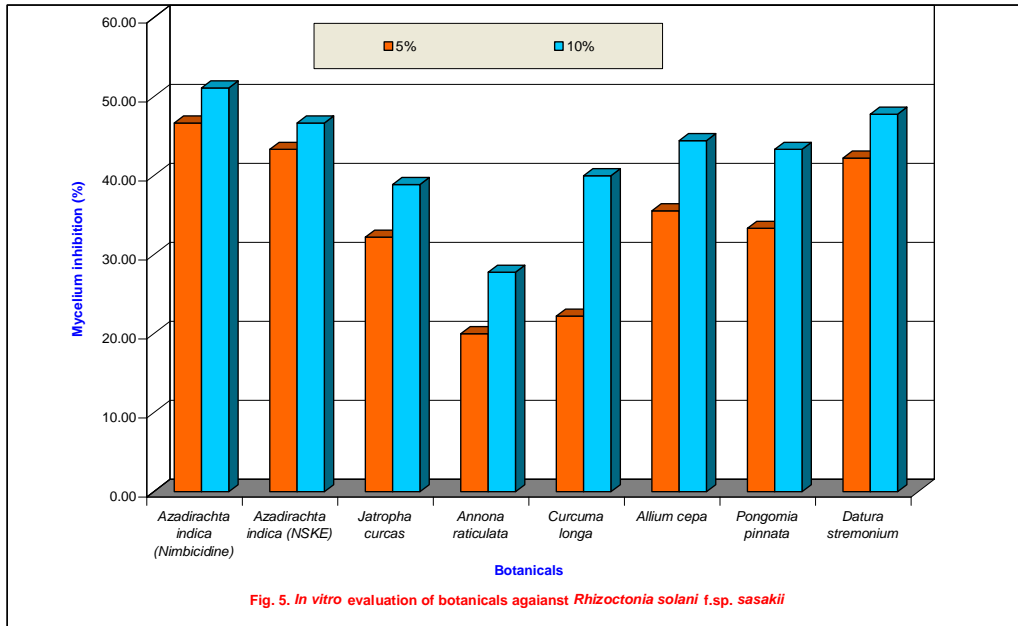


Fig. 5. In vitro evaluation of botanicals against *Rhizoctonia solani* f.sp. sasakii

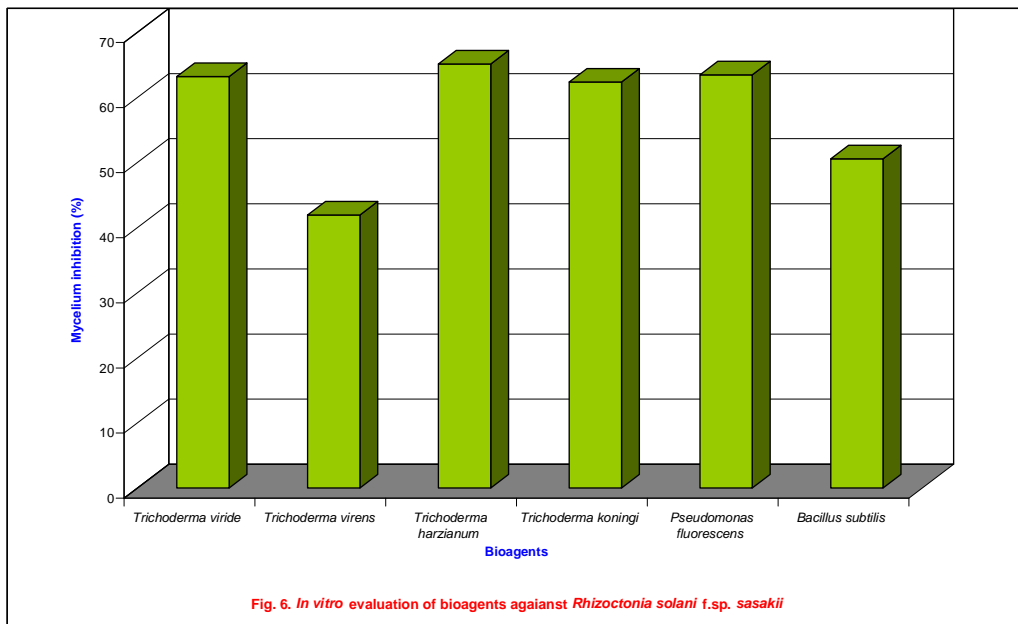
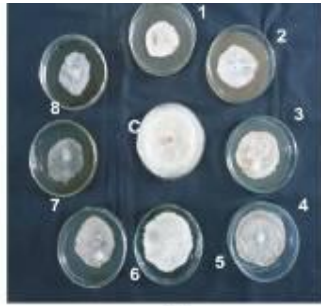


Fig. 6. In vitro evaluation of bioagents against *Rhizoctonia solani* f.sp. sasakii

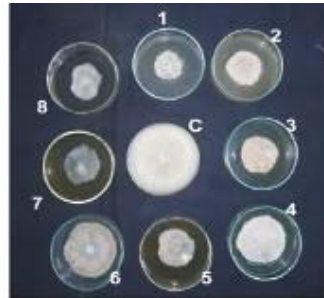


5%

C - Control

- 1- Azardiachta indica (neem oil)
- 2- Azardiachta indica (NSKE)
- 3- Jatropha curcas
- 4- Annona raticulata

- 5- Curcuma longa
- 6- Allium cepa
- 7- Pongomia pinnata
- 8- Datura stremonium



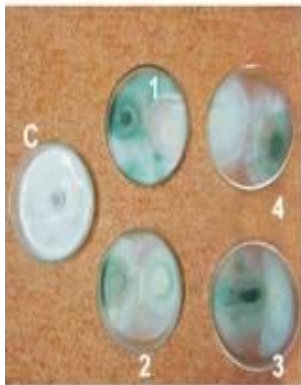
10%

C - Control

- 1- Azardiachta indica (neem oil)
- 2- Azardiachta indica (NSKE)
- 3- Jatropha curcas
- 4- Annona raticulata

- 5- Curcuma longa
- 6- Allium cepa
- 7- Pongomia pinnata
- 8- Datura stremonium

Plate 6: *In vitro* evaluation of botanicals against *Rhizoctonia solani* f. sp. *sasakii*



C - Control

- 1-Trichoderma harzianum
- 2- Trichoderma viride
- 3- Trichoderma virens
- 4- Trichoderma koningi
- 5- Pseudomonas fluorescens
- 6- Bacillus subtilis



C - Control

- 1-Trichoderma harzianum
- 2- Trichoderma viride
- 3- Trichoderma virens
- 4- Trichoderma koningi
- 5- Pseudomonas fluorescens
- 6- Bacillus subtilis

Plate 7: *In vitro* evaluation of bioagents against *Rhizoctonia solani* f. sp. *sasakii*

Among the four non systemic fungicides and one antibiotic tested Mancozeb 75 WP found to be most effective at all the concentrations. Copper oxychloride 50 WP was found to be least effective.

4.5.2 *In vitro* evaluation of botanicals against *Rhizoctonia solani* f. sp. *sasakii*

Antifungal activity of eight plant extracts with different concentrations was assayed using the poison food technique as described in material and methods. The radial growth of the fungus was recorded at 4 days after incubation at 28 ± 2 °C and per cent inhibition was calculated. The results are presented in Table 6 and depicted in Plate 6, Fig. 5. The data revealed that the mycelial growth inhibition varied significantly with different treatments. Among the eight plant extracts tested, maximum inhibition of 46.67 per cent of mycelial growth was recorded in *Azadirachta indica* oil (nimbicidin) at five per cent concentration which was significantly superior to all other treatments followed by neem seed kernel extract (43.33%) and Datura seed extract (41.18%). Least mycelial inhibition at five per cent concentration was observed with custard apple seed extract (20.02%) followed by turmeric leaf extract (22.22%).

At ten per cent concentration maximum inhibition of mycelial growth was recorded in *Azadirachta indica* oil treatment (51.11%) which was significantly superior to all other treatments. Least mycelial inhibition was observed in custard apple seed extract (27.78%) and turmeric leaf extract (11.85%) at ten per cent concentration.

4.5.3 *In vitro* evaluation of bioagents against *Rhizoctonia solani* f. sp. *sasakii*

The antagonistic effect of four fungi and two bacteria was assayed by inhibition zone technique as explained in the material and methods. The results are presented in the Table 7 and depicted in Fig. 6 and Plate 7. Results clearly indicated that antagonistic fungi significantly suppressed the growth of *Rhizoctonia solani* f. sp. *sasakii*. *Trichoderma harzianum* inhibited maximum mycelial growth (65.13%), which was found on par with *Pseudomonas fluorescens* (63.45%), *Trichoderma viride* (63.19%) and *Trichoderma koningi* (62.35%). *Bacillus subtilis* (50.55%) suppressed the growth of *Rhizoctonia solani* f. sp. *sasakii*. Least inhibition was noticed in *Trichoderma virens* (41.94%).

4.6 Management of the disease

Field experiment was conducted during *Kharif* season of 2012 to assess the possibility of managing the disease by different combination of four seed dressing fungicides and two bioagents along with foliar spray with eleven fungicide and two bioagents. The data on management of disease is presented in Tables 8 to 14 and Plate 8.

4.6.1 Effect of seed treatment and foliar spray with chemical and bioagents on per cent disease index

The result revealed that, statistically significant differences among the treatments for PDI. PDI significantly differed by seed treatment of different chemicals and biocontrol agents and foliar application of chemicals and biocontrol agents and are given in Table 8 and 9.

Seed treatment differed significantly with respect to PDI. Minimum PDI was observed in the treatment, viz., S1: Seed treatment with *Pseudomonas fluorescens* @ 10g kg⁻¹ of seed (32.84%) over control (40.04%) and was statistically on par with S6: Carbendazim 50 WP @ 2.5 g Kg⁻¹ (34.64%) and S5: seed treatment with Carboxin 37.5% + Thiram 37.5% @ 2.5 g Kg⁻¹ (35.04%). Maximum increased per cent disease control over untreated recorded in treatment, viz., S1 (49.95%) over control (38.97%) followed by S6 (47.66%) and S5 (46.07%). Foliar spray differed significantly with respect to PDI. Minimum PDI was observed in the treatment, viz., F4: Two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS (22.94%) over control (60.94%) and was statistically on par with F3: Hexaconazole 5 EC @ 0.1% (27.04%), F6: Carbendazim 50 WP @ 0.1% (27.74%) and F9: Carbendazim 12%+ Mancozeb 63% @ 0.2% (31.14%). Maximum increased per cent disease control over untreated recorded in treatment, viz., F4 (65.03%) over control (7.10%) followed by F3 (58.78%), F6 (57.71%) and F9 (52.53%). Interaction effect of seed treatment and foliar spray differ significantly with respect to Stover yield ha⁻¹. The treatment, viz., S1F4: seed treatment with *Pseudomonas fluorescens* @ 10 g l⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS gave minimum PDI (20.40%) over control (65.60%) and was statistically on par with S5F4 seed treatment with Carbendazim 50 WP @ 2.5 g Kg⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% (21.20%), S1F3: *Pseudomonas fluorescens* @ 10g/l combined with two sprays of Hexaconazole 5 EC @ 0.1% (21.5%), S6F4: Carbendazim 50 WP @ 2.5 g Kg⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% (22.90%).

Table 7. In vitro evaluation of bioagents against *Rhizoctonia solani* f. sp. *sasakii*

Antagonist	Per cent inhibition of mycelial growth
<i>Trichoderma viride</i> Pers. ex. Fr.	63.19 (52.67)*
<i>Trichoderma virens</i> Rifai	41.94 (40.37)
<i>Trichoderma harzianum</i> Miller	65.13 (53.83)
<i>Trichoderma koningi</i> Rifai.	62.35 (52.18)
<i>Pseudomonas fluorescens</i> Migula	63.45 (52.53)
<i>Bacillus subtilis</i> (Ehrenberg) Cohn	50.55 (45.34)
Mean	57.76 (48.41)
S.Em ±	0.55
C.D. at 1%	2.29

* Figures in the parentheses indicate arc sine transformed values

Table 8. Effect of seed treatment and foliar spray with chemicals and bioagents on per cent disease index of banded leaf and sheath blight

Foliar spray	Per cent disease index (PDI)							Mean
	Seed treatment							
	S1	S2	S3	S4	S5	S6	S7	
F1	37.5(37.78)*	41.1(39.89)	39(38.67)	44.7(41.98)	39.3(38.84)	39(39.08)	39.7(38.67)	40.04(39.27)
F2	27.9(31.90)	31.5(34.16)	29.4(32.85)	35.1(36.35)	29.7(33.04)	29.4(33.29)	30.1(32.25)	30.44(33.49)
F3	21.5(29.68)	28.1(32.03)	26(30.67)	31.7(34.28)	26.3(30.87)	26(31.13)	26.7(30.67)	27.04(31.34)
F4	20.4(26.86)	24(29.35)	24.9(27.92)	27.6(31.71)	21.2(28.12)	22.9(28.40)	22.6(27.92)	22.94(28.61)
F5	58.4(49.86)	62(51.97)	59.9(50.74)	65.6(54.12)	60.2(50.91)	59.9(51.15)	60.6(50.74)	60.94(51.35)
F6	28.9(32.54)	32.5(34.77)	30.4(33.48)	36.1(36.95)	30.7(33.66)	30.4(33.91)	31.1(33.48)	27.74(34.11)
F7	40.5(39.54)	44.1(41.63)	42(40.42)	47.7(43.70)	42.3(40.59)	42(40.82)	42.7(40.42)	43.04(41.02)
F8	37.4(37.72)	41(39.84)	38.9(38.61)	44.6(41.92)	39.2(38.78)	38.9(39.02)	39.6(38.61)	39.94(39.21)
F9	25.2(32.35)	28.8(34.59)	26.7(33.29)	32.4(36.77)	27(33.48)	26.7(33.73)	27.4(33.29)	31.14(33.93)
F10	28.6(30.15)	32.2(32.47)	30.1(31.13)	35.8(34.71)	30.4(31.32)	30.1(31.58)	30.8(31.13)	31.44(31.79)
F11	35.2(36.41)	38.8(38.55)	36.7(37.31)	42.4(40.65)	37(37.48)	36.7(37.72)	37.4(37.31)	37.74(37.92)
F12	32.3(34.65)	35.9(36.83)	33.8(35.57)	39.5(38.96)	34.1(35.75)	33.8(35.99)	34.5(35.57)	34.84(36.19)
F13	33.5(35.38)	37.1(37.54)	35(36.29)	40.7(39.66)	35.3(36.47)	35(36.71)	35.7(36.29)	36.04(36.91)
F14	27.5(31.64)	31.1(33.91)	29(32.60)	34.7(36.11)	29.3(32.79)	29(33.04)	29.7(32.60)	30.04(33.24)
Mean	32.84(34.86)	36.44(37.06)	34.34(35.78)	40.04(39.22)	34.64(35.97)	34.34(36.21)	35.04(35.78)	
For comparison of mean						Seed treatment (S)	Foliar Spray (F)	S X F
S. Em ±						0.79	1.97	2.34
C. D.at 5%						2.21	5.52	6.55

*Figures in the parentheses indicate arc sine transformed values

S1: *Pseudomonas fluorescens* @10 g/kg

S2: *Trichoderma harzianum* @10 g/kg

S3: Tebuconazole 50 WG @1.5 g/kg

S4: Untreated Control,

S5: Carboxin 36.5 % + Thiram 36.5 % @2.5 g/kg

S6: Carbendazim 50 WP @ 3.25 g/kg.

S7: Mancozeb 50% + Carbendazim 25% 2.5 g/kg

F1: Difenconazole 25 EC @1 ml/l,

F2: Tebuconazole 250 EC @1 ml/l

F3: Hexaconazole 5 EC @1 ml/l

F4: Propiconazole 25 EC @1ml/l

F5: Untreated control

F6: Carbendazim 50 WP @1g/l @ 2.5 g/l

F7: *Pseudomonas fluorescens* @10g/l

F8: Mancozeb 75WP@3g/l

F9: Carbendazim 12 %+ Mancozeb 63 % @2g/l

F10: Carboxin 36.5 % + Thiram 36.5 % @2g/l

F11: *Trichoderma harzianum*@10g/l

F12: Hexaconazole 4 % +Zineb 68 % @2g/l

F13 Tricyclozole 18 % + Mancozeb 62 % @2g/l

F14: Trifloxystrobin 25 % + Tebuconazole 50% @1g/l

Table 9. Effect of seed treatment and foliar spray with chemicals and bioagents on per cent disease control over untreated

Foliar spray	Per cent disease control							Mean
	Seed treatment							
	S1	S2	S3	S4	S5	S6	S7	
F1	42.84	37.35	40.55	31.86	40.09	39.48	40.55	38.96
F2	57.47	51.98	55.18	46.49	54.73	54.12	55.18	53.59
F3	65.65	57.16	60.37	51.68	59.91	59.30	60.37	58.78
F4	68.90	63.41	65.12	57.93	66.66	65.55	65.62	65.03
F5	10.98	5.49	8.69	0.00	8.23	7.62	8.69	7.10
F6	61.59	56.10	59.30	50.61	58.84	58.23	59.30	57.71
F7	38.26	32.77	35.98	27.29	35.52	34.91	35.98	34.39
F8	42.99	37.50	40.70	32.01	40.24	39.63	40.70	39.11
F9	56.40	50.91	54.12	45.43	53.66	53.05	54.12	52.53
F10	55.95	50.46	53.66	44.97	53.20	52.59	53.66	52.07
F11	46.34	40.85	44.05	35.37	43.60	42.99	44.05	42.47
F12	50.76	45.27	48.48	39.79	48.02	47.41	48.48	46.89
F13	48.93	43.45	46.65	37.96	46.19	45.58	46.65	45.06
F14	58.08	52.59	55.79	47.10	55.34	54.73	55.79	54.20
Mean	49.95	44.46	47.66	38.97	47.20	46.59	47.66	

S1: *Pseudomonas fluorescens* @10 g/kg
 S2: *Trichoderma harzianum* @10 g/kg
 S3: Tebuconazole 50 WG @1.5 g/kg
 S4: Untreated Control,
 S5: Carboxin 36.5 % + Thiram 36.5 % @2.5 g/kg
 S6: Carbendazim 50 WP @ 3.25 g/kg.
 S7: Mancozeb 50% + Carbendazim 25% 2.5 g/kg

F1: Difenconazole 25 EC @1 ml/l,
 F2: Tebuconazole 250 EC @1 ml/l
 F3: Hexaconazole 5 EC @1 ml/l
 F4: Propiconazole 25 EC @1ml/l
 F5: Untreated control
 F6: Carbendazim 50 WP @1g/l @ 2.5 g/l
 F7: *Pseudomonas fluorescens* @10g/l

F8: Mancozeb 75WP@3g/l
 F9: Carbendazim 12 %+ Mancozeb 63 % @2g/l
 F10: Carboxin 36.5 % + Thiram 36.5 % @2g/l
 F11: *Trichoderma harzianum*@10g/l
 F12: Hexaconazole 4 % +Zineb 68 % @2g/l
 F13 Tricyclozole 18 % + Mancozeb 62 % @2g/l
 F14: Trifloxystrobin 25 % + Tebuconazole 50% @1g/l

Table 10: Effect of seed treatment and foliar spray with chemicals and bioagents on grain yield of maize

Foliar Spray	Grain yield (q/ha)							Mean
	Seed treatment							
	S1	S2	S3	S4	S5	S6	S7	
F1	72.89	69.49	70.09	67.69	71.39	71.09	70.69	70.48
F2	73.5	70.12	70.72	68.34	72.12	71.71	71.3	71.09
F3	78.24	74.84	75.44	73.04	76.74	76.44	76.04	75.83
F4	80.42	77.02	77.62	75.22	78.62	78.92	78.22	78.01
F5	62.35	58.95	59.55	57.15	60.85	60.55	60.15	59.94
F6	78.16	74.96	75.56	73.16	76.86	76.56	76.16	75.72
F7	69.54	66.14	66.74	64.34	68.04	67.74	67.34	67.13
F8	68.54	65.14	65.74	63.34	67.04	66.74	66.34	66.13
F9	75.42	72.10	72.61	70.21	73.92	73.62	73.22	72.99
F10	71.54	68.14	68.74	66.34	70.04	69.74	69.34	69.13
F11	72.25	68.85	69.45	67.05	70.75	70.45	70.05	69.84
F12	69.54	66.14	66.74	64.34	68.04	67.74	67.34	67.13
F13	69.75	66.35	66.95	64.55	68.25	67.95	67.55	67.34
F14	74.35	70.95	71.55	69.15	72.85	72.55	72.15	71.94
Mean	72.08	68.68	69.28	66.88	70.09	70.28	69.88	
For comparison of mean			Seed treatment (S)	Foliar spray (F)	S X F			
S. Em ±			0.74	1.84	2.45			
C. D.at 5%			2.07	5.15	6.86			

S1: *Pseudomonas fluorescens* @10 g/kg
 S2: *Trichoderma harzianum* @10 g/kg
 S3: Tebuconazole 50 WG @1.5 g/kg
 S4: Untreated Control,
 S5: Carboxin 36.5 % + Thiram 36.5 % @2.5 g/kg
 S6: Carbendazim 50 WP @ 3.25 g/kg.
 S7: Mancozeb 50% + Carbendazim 25% 2.5 g/kg

F1: Difenconazole 25 EC @1 ml/l,
 F2: Tebuconazole 250 EC @1 ml/l
 F3: Hexaconazole 5 EC @1 ml/l
 F4: Propiconazole 25 EC @1ml/l
 F5: Untreated control
 F6: Carbendazim 50 WP @1g/l @ 2.5 g/l
 F7: *Pseudomonas fluorescens* @10g/l

F8: Mancozeb 75WP@3g/l
 F9: Carbendazim 12 %+ Mancozeb 63 % @2g/l
 F10: Carboxin 36.5 % + Thiram 36.5 % @2g/l
 F11: *Trichoderma harzianum*@10g/l
 F12: Hexaconazole 4 % +Zineb 68 % @2g/l
 F13 Tricyclozole 18 % + Mancozeb 62 % @2g/l
 F14: Trifloxystrobin 25 % + Tebuconazole 50% @1g/l

Table 11. Field efficacy of seed treatment and foliar spray with chemicals and bioagents on per cent increase in grain yield over untreated

Foliar spray	Per cent increase in grain yield							Mean
	Seed treatment							
	S1	S2	S3	S4	S5	S6	S7	
F1	27.54	21.59	22.64	18.44	24.39	24.92	23.69	23.32
F2	28.61	22.66	23.71	19.51	25.46	25.98	24.76	24.38
F3	37.90	30.95	32.00	27.80	33.75	34.28	33.05	32.98
F4	40.72	34.77	35.82	31.62	38.09	37.16	36.87	36.49
F5	9.10	3.15	4.20	-	5.95	6.47	5.25	4.87
F6	37.57	31.16	32.21	28.01	33.96	34.49	33.26	32.89
F7	21.68	15.73	16.78	12.58	18.53	19.06	17.83	17.46
F8	19.93	13.98	15.03	10.83	16.78	17.31	16.08	15.71
F9	31.93	25.98	27.03	22.83	28.78	29.31	28.08	27.71
F10	25.18	19.23	20.28	16.08	22.03	22.55	21.33	20.95
F11	26.42	20.47	21.52	17.32	23.27	23.80	22.57	22.20
F12	21.68	15.73	16.78	12.58	18.53	19.06	17.83	17.46
F13	22.05	16.10	17.15	12.95	18.90	19.42	18.20	17.82
F14	30.10	24.15	25.20	21.00	26.95	27.47	26.25	25.87
Mean	26.13	20.18	21.23	17.03	22.98	23.50	22.28	

S1: *Pseudomonas fluorescens* @10 g/kg
 S2: *Trichoderma harzianum* @10 g/kg
 S3: Tebuconazole 50 WG @1.5 g/kg
 S4: Untreated Control,
 S5: Carboxin 36.5 % + Thiram 36.5 % @2.5 g/kg
 S6: Carbendazim 50 WP @ 3.25 g/kg.
 S7: Mancozeb 50% + Carbendazim 25% 2.5 g/kg

F1: Difenconazole 25 EC @1 ml/l,
 F2: Tebuconazole 250 EC @1 ml/l
 F3: Hexaconazole 5 EC @1 ml/l
 F4: Propiconazole 25 EC @1ml/l
 F5: Untreated control
 F6: Carbendazim 50 WP @1g/l @ 2.5 g/l
 F7: *Pseudomonas fluorescens* @10g/l

F8: Mancozeb 75WP@3g/l
 F9: Carbendazim 12 %+ Mancozeb 63 % @2g/l
 F10: Carboxin 36.5 % + Thiram 36.5 % @2g/l
 F11: *Trichoderma harzianum*@10g/l
 F12: Hexaconazole 4 % +Zineb 68 % @2g/l
 F13 Tricyclozole 18 % + Mancozeb 62 % @2g/l
 F14: Trifloxystrobin 25 % + Tebuconazole 50% @1g/l

Maximum increased per cent disease control over untreated recorded in treatment, viz., S1F4 (68.90%) over control (0.00%) followed by S5F4 (66.66%), S1F3 (65.65%) and S6F4 (65.55%).

4.6.2 Effect of seed treatment and foliar spray with chemical and bioagents on grain yield of maize

The result revealed that, statistically significant differences among the treatments for grain yield. Grain yield significantly differed by seed treatment of different chemicals and biocontrol agents and foliar applications were given in Tables 10, and 11.

Seed treatment differed significantly with respect to seed yield ha⁻¹. Maximum grain yield was observed in the treatment, viz., S1: Seed treatment with *Pseudomonas fluorescens* @10g kg⁻¹ of seed (72.08 q ha⁻¹) over control (66.88 q ha⁻¹) and was statistically on par with S6: Carbendazim 50 WP @ 2.5 g Kg⁻¹ (70.28 q ha⁻¹) and S5: seed treatment with Carboxin 37.5% + Thiram 37.5% @ 2.5 g Kg⁻¹ (70.09 q ha⁻¹). Maximum increased in grain yield was observed in S1 (26.13%) over control (17.03%) followed by S6 (23.50%) and S5 (22.98%).

Foliar spray differed significantly with respect to grain yield ha⁻¹. Maximum grain yield was observed in the treatment, viz., F4: Two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS (78.01 q ha⁻¹) over control (59.94 q ha⁻¹) and was statistically on par with F3: Hexaconazole 5 EC @ 0.1% (75.83 q ha⁻¹), F6: Carbendazim 50 WP @ 0.1% (75.72 q ha⁻¹) and F9: Carbendazim 12%+ Mancozeb 63 0.2% (72.99 q ha⁻¹). Maximum increased in grain yield was observed in F4 (36.49%) over control (4.87%) followed by F3 (32.98%), F6 (32.89%) and F9 (27.71%).

Interaction effect of seed treatment and foliar spray differ significantly with respect to grain yield ha⁻¹. The treatment, viz., S1F4: seed treatment with *Pseudomonas fluorescens* @10 g l⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS gave maximum grain yield (80.42 q ha⁻¹) over control (57.15 q ha⁻¹), was statistically on par with S5F4 seed treatment with Carbendazim 50 WP @ 2.5 g Kg⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% (78.92 q ha⁻¹), S1F3: *Pseudomonas fluorescens* @10g/l combined with two sprays of Hexaconazole 5 EC @ 0.1% (78.24 q ha⁻¹), S1F6: *Pseudomonas fluorescens* @10g/l combined with two sprays of Carbendazim 50 WP @ 0.1% (78.16 q ha⁻¹). Maximum increased in grain yield was observed in S1F4 (40.72%) over control (0.00%) followed by S5F4 (38.09%) S1F3 (37.90%), S1F6 (37.16%).

4.6.3 Effect of seed treatment and foliar spray with chemical and bioagents on stover yield of maize

The result revealed that, statistically significant differences among the treatments for Stover yield. Stover yield significantly differed by seed treatment of different chemicals and biocontrol agents and foliar application of chemicals and biocontrol agents and are given in Tables 12 and 13.

Seed treatment differed significantly with respect to Stover yield ha⁻¹. Maximum Stover yield was observed in the treatment, viz., S1: Seed treatment with *Pseudomonas fluorescens* @10g kg⁻¹ of seed (9.47 t ha⁻¹) over control (8.17 t ha⁻¹) and was statistically on par with S6: Carbendazim 50 WP @ 2.5 g Kg⁻¹ (9.02 t ha⁻¹) and S5: seed treatment with Carboxin 37.5% + Thiram 37.5% @ 2.5 g Kg⁻¹ (8.97 t ha⁻¹). Maximum increased in Stover yield was observed in S1 (27.49%) over control (9.99%) followed by S6 (21.43%) and S5 (20.76%).

Foliar spray differed significantly with respect to Stover yield ha⁻¹. Maximum Stover yield was observed in the treatment, viz., F4: Two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS (10.10 t ha⁻¹) over control (8.08 t ha⁻¹) and was statistically on par with F3: Hexaconazole 5 EC @ 0.1% (9.89 t ha⁻¹), F6: Carbendazim 50 WP @ 0.1% (9.69 t ha⁻¹) and F9: Carbendazim 12%+ Mancozeb 63 0.2% (9.58 t ha⁻¹). Maximum increased in Stover yield was observed in F4 (35.94%) over control (8.75%) followed by F3 (33.11%), F6 (30.42%) and F9 (28.94%). Highest avoidable loss recorded in treatment, viz., F4 (26.33%) over control (24.77%) followed by F3 (23.21%), F6 (29.09%) and F9 (22.32%).

Interaction effect of seed treatment and foliar spray differ significantly with respect to Stover yield ha⁻¹. The treatment, viz., S1F4: seed treatment with *Pseudomonas fluorescens* @10 g l⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS gave maximum Stover yield (10.75 t ha⁻¹) over control (7.43 t ha⁻¹) and was statistically on par with S5F4 seed treatment with Carbendazim 50 WP @ 2.5 g Kg⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% (10.56 t ha⁻¹), S1F3: *Pseudomonas fluorescens* @10g/l combined with two sprays of Hexaconazole 5 EC @ 0.1% (10.54 t ha⁻¹), S1F6: *Pseudomonas fluorescens* @10g/l combined with two sprays of Carbendazim 50 WP @ 0.1% (10.23 t ha⁻¹). Maximum increased in Stover yield was observed in S1F4 (44.68%) over control (0.00%) followed by S5F4 (42.34%) S1F3 (41.86%), S1F6 (39.17%).

Table 12. Effect of seed treatment and foliar spray with chemicals and bioagents on stover yield of maize

Foliar spray	Stover yield (t/ha)							Mean
	Seed treatment							
	S1	S2	S3	S4	S5	S6	S7	
F1	9.11	8.22	8.35	7.81	8.61	8.66	8.46	8.46
F2	10.11	9.22	9.35	8.81	9.61	9.66	9.46	9.46
F3	10.54	9.65	9.78	9.24	10.04	10.09	9.89	9.89
F4	10.75	9.86	9.99	9.45	10.56	10.03	10.1	10.10
F5	8.73	7.84	7.97	7.43	8.23	8.28	8.08	8.08
F6	10.34	9.45	9.58	9.04	9.84	9.89	9.69	9.69
F7	9.45	8.56	8.69	8.15	8.95	9.00	8.8	8.80
F8	8.98	8.09	8.22	7.68	8.48	8.53	8.33	8.33
F9	10.23	9.34	9.47	8.93	9.73	9.78	9.58	9.58
F10	9.34	8.45	8.58	8.04	8.84	8.89	8.69	8.69
F11	9.41	8.52	8.65	8.11	8.91	8.96	8.76	8.76
F12	9.34	8.45	8.58	8.04	8.84	8.89	8.69	8.69
F13	9.24	8.35	8.48	7.94	8.74	8.79	8.59	8.59
F14	9.47	8.58	8.71	8.17	8.97	9.02	8.82	8.82
Mean	9.47	8.58	8.71	8.17	8.97	9.02	8.82	
For comparison of mean			Seed treatment (S)	Foliar spray (F)	S X F			
S.Em ±			0.19	0.45	0.63			
C.D.at 5%			0.51	1.27	1.78			

S1: *Pseudomonas fluorescens* @10 g/kg
 S2: *Trichoderma harzianum* @10 g/kg
 S3: Tebuconazole 50 WG @1.5 g/kg
 S4: Untreated Control,
 S5: Carboxin 36.5 % + Thiram 36.5 % @2.5 g/kg
 S6: Carbendazim 50 WP @ 3.25 g/kg.
 S7: Mancozeb 50% + Carbendazim 25% 2.5 g/kg

F1: Difenconazole 25 EC @1 ml/l,
 F2: Tebuconazole 250 EC @1 ml/l
 F3: Hexaconazole 5 EC @1 ml/l
 F4: Propiconazole 25 EC @1ml/l
 F5: Untreated control
 F6: Carbendazim 50 WP @1g/l @ 2.5 g/l
 F7: *Pseudomonas fluorescens* @10g/l

F8: Mancozeb 75WP@3g/l
 F9: Carbendazim 12 %+ Mancozeb 63 % @2g/l
 F10: Carboxin 36.5 % + Thiram 36.5 % @2g/l
 F11: *Trichoderma harzianum*@10g/l
 F12: Hexaconazole 4 % +Zineb 68 % @2g/l
 F13 Tricyclozole 18 % + Mancozeb 62 % @2g/l
 F14: Trifloxystrobin 25 % + Tebuconazole 50% @1g/l

Table 13. Field efficacy of seed treatment and foliar spray with chemicals and bioagents on per cent increased in stover yield over untreated

Foliar spray	Per cent increased in stover yield							Mean
	Seed treatment							
	S1	S2	S3	S4	S5	S6	S7	
F1	22.61	10.63	12.38	5.11	15.88	16.55	13.86	13.86
F2	36.07	24.09	25.84	18.57	29.34	30.01	27.32	27.32
F3	41.86	29.88	31.63	24.36	35.13	35.80	33.11	33.11
F4	44.68	32.71	34.45	27.19	42.34	38.63	35.94	35.94
F5	17.50	5.52	7.27	-	10.77	11.44	8.75	8.75
F6	39.17	27.19	28.94	21.67	32.44	33.11	30.42	30.42
F7	27.19	15.21	16.96	9.69	20.46	21.13	18.44	18.44
F8	20.86	8.88	10.63	3.36	14.13	14.80	12.11	12.11
F9	37.69	25.71	27.46	20.19	30.96	31.63	28.94	28.94
F10	25.71	13.73	15.48	8.21	18.98	19.65	16.96	16.96
F11	26.65	14.67	16.42	9.15	19.92	20.59	17.90	17.90
F12	25.71	13.73	15.48	8.21	18.98	19.65	16.96	16.96
F13	24.36	12.38	14.13	6.86	17.63	18.30	15.61	15.61
F14	27.46	15.48	17.23	9.96	20.73	21.40	18.71	18.71
Mean	27.49	15.51	17.26	9.99	20.76	21.43	18.74	

S1: *Pseudomonas fluorescens* @10 g/kg
 S2: *Trichoderma harzianum* @10 g/kg
 S3: Tebuconazole 50 WG @1.5 g/kg
 S4: Untreated Control,
 S5: Carboxin 36.5 % + Thiram 36.5 % @2.5 g/kg
 S6: Carbendazim 50 WP @ 3.25 g/kg.
 S7: Mancozeb 50% + Carbendazim 25% 2.5 g/kg

F1: Difenconazole 25 EC @1 ml/l,
 F2: Tebuconazole 250 EC @1 ml/l
 F3: Hexaconazole 5 EC @1 ml/l
 F4: Propiconazole 25 EC @1ml/l
 F5: Untreated control
 F6: Carbendazim 50 WP @1g/l @ 2.5 g/l
 F7: *Pseudomonas fluorescens* @10g/l

F8: Mancozeb 75WP@3g/l
 F9: Carbendazim 12 %+ Mancozeb 63 % @2g/l
 F10: Carboxin 36.5 % + Thiram 36.5 % @2g/l
 F11: *Trichoderma harzianum*@10g/l
 F12: Hexaconazole 4 % +Zineb 68 % @2g/l
 F13 Tricyclozole 18 % + Mancozeb 62 % @2g/l
 F14: Trifloxystrobin 25 % + Tebuconazole 50% @1g/l

4.6.4 Effect of seed treatment and foliar spray with chemical and bioagents on 100 grain weight

The result revealed that, statistically significant differences among the treatments for 100 grain weight. 100 grain weight treatment significantly differed by seed treatment of different chemicals and biocontrol agents and foliar application of chemicals and biocontrol agents and are given in Table 14.

Seed treatment differed significantly with respect to 100 grain weight. Maximum 100 grain weight was observed in the treatment, viz., S1: Seed treatment with *Pseudomonas fluorescens* @10g kg⁻¹ of seed (34.85 g) over control (28.15 g) and was statistically on par with S6: Carbendazim 50 WP @ 2.5 g Kg⁻¹ (34.11 g) and S5: seed treatment with Carboxin 37.5% + Thiram 37.5% @ 2.5 g Kg⁻¹ (34.04 g).

Foliar spray differed significantly with respect to 100 grain weight. Maximum 100 grain weight was observed in the treatment, viz., F4: Two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS (36.66 g) over control (26.69 g) and was statistically on par with F3: Hexaconazole 5 EC @ 0.1% (35.56 g), F6: Carbendazim 50 WP @ 0.1% (35.04 g) and F9: Carbendazim 12%+ Mancozeb 63 0.2% (34.65 g).

Interaction effect of seed treatment and foliar spray differ significantly with respect to 100 grain weight. The treatment, viz., S1F4: seed treatment with *Pseudomonas fluorescens* @10 g l⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS gave 100 grain weight (39.51 g) over control (22.84 g) and was statistically on par with S5F4 seed treatment with Carbendazim 50 WP @ 2.5 g Kg⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% (38.70 g), S1F3: *Pseudomonas fluorescens* @10g/l combined with two sprays of Hexaconazole 5 EC @ 0.1% (38.41 g), S1F6: *Pseudomonas fluorescens* @10g/l combined with two sprays of Carbendazim 50 WP @ 0.1% (37.89 g).

Table 14. Effect of seed treatment and foliar spray with chemicals and bioagents on 100 seed weight

Foliar spray	100 seed weight (g)							Mean
	Seed treatment							
	S1	S2	S3	S4	S5	S6	S7	
F1	32.40	27.90	29.20	25.70	31.59	31.66	28.40	29.55
F2	34.20	29.70	31.00	27.50	33.39	33.46	30.20	31.35
F3	38.41	33.91	35.21	31.71	37.60	37.67	34.41	35.56
F4	39.51	35.01	36.31	32.81	38.70	37.69	35.51	36.66
F5	29.54	25.04	26.34	22.84	28.73	28.80	25.54	26.69
F6	37.89	33.39	34.69	31.19	37.08	37.15	33.89	35.04
F7	32.40	27.90	29.20	25.70	31.59	31.66	28.40	29.55
F8	34.40	29.90	31.20	27.70	33.59	33.66	30.40	31.55
F9	37.50	33.00	34.30	30.80	36.69	36.76	33.50	34.65
F10	36.33	31.83	33.13	29.63	35.52	35.59	32.33	33.48
F11	33.45	28.95	30.25	26.75	32.64	32.71	29.45	30.60
F12	34.20	29.70	31.00	27.50	33.39	33.46	30.20	31.35
F13	34.60	30.10	31.40	27.90	33.79	33.86	30.60	31.75
F14	36.23	31.73	33.03	29.53	35.42	35.49	32.23	33.38
Mean	34.85	30.35	31.65	28.15	34.04	34.11	30.85	
For comparison of mean						Seed treatment (S)	Foliar spray (F)	S X F
S. Em ±						0.46	1.15	1.51
C. D.at 5%						1.29	3.22	4.23

S1: *Pseudomonas fluorescens* @10 g/kg

S2: *Trichoderma harzianum* @10 g/kg

S3: Tebuconazole 50 WG @1.5 g/kg

S4: Untreated Control,

S5: Carboxin 36.5 % + Thiram 36.5 % @2.5 g/kg

S6: Carbendazim 50 WP @ 3.25 g/kg.

S7: Mancozeb 50% + Carbendazim 25% 2.5 g/kg

F1: Difenconazole 25 EC @1 ml/l,

F2: Tebuconazole 250 EC @1 ml/l

F3: Hexaconazole 5 EC @1 ml/l

F4: Propiconazole 25 EC @1ml/l

F5: Untreated control

F6: Carbendazim 50 WP @1g/l @ 2.5 g/l

F7: *Pseudomonas fluorescens* @10g/l

F8: Mancozeb 75WP@3g/l

F9: Carbendazim 12 %+ Mancozeb 63 % @2g/l

F10: Carboxin 36.5 % + Thiram 36.5 % @2g/l

F11: *Trichoderma harzianum*@10g/l

F12: Hexaconazole 4 % +Zineb 68 % @2g/l

F13 Tricyclozole 18 % + Mancozeb 62 % @2g/l

F14: Trifloxystrobin 25 % + Tebuconazole 50% @1g/l



A



B



A. Seed treatment with *Pseudomonas fluorescens* @10 g/kg combined with two sprays of Propiconazole 25 EC @ 0.1 %



A. Seed treatment with *Pseudomonas fluorescens* @10 g/kg combined with two sprays of Propiconazole 25 EC @ 0.1 %

Plate 8: Management of disease with seed treatment and foliar spray

DISCUSSION

Among the cereals, maize is wide spread crop next to wheat and rice in the world and ranks fourth after rice, wheat and sorghum. Maize is one of the most important cereal crops in the world, grown over an area of 174.2 m ha. In Indian agriculture, maize occupies an important place with an area of 8.67 m ha. It is not only utilized as a staple food by the lower strata of the society but it is also a crop of par excellence for industrial use. In India, it is consumed both as food and stover, human food accounts for about 50 to 55 per cent while the remaining is used in industry and poultry sector. In the near future, demand for maize is expected to increase because of its many uses. It is the main raw material for products like glucose, sorbitol, dextrose and oil. Also used in livestock, poultry and animal feed, manufacture of starch and starch based products. It can contribute to diet diversification and improve nutrition in human being through exploitation of quality protein maize (Singhal, 2003).

Among 18 foliar diseases reported in India banded leaf and sheath blight of maize caused by *Rhizoctonia solani* f.sp. *sasakii* Exner (*Thanatephorus sasakii* (Shirai) Tu & Kimbro) is considered as one of the most important disease of maize, capable of causing appreciable damage to standing crop to an extent of 100 per cent (Singh and Sharma, 1976). Banded leaf and sheath blight of maize appears in isolated area in Karnataka. It is difficult to manage the disease through fungicides alone, as it does not give protection throughout the crop growth period. Biological control of the pathogen is usually cheaper and fits well in the frame work of integrated disease management system for sustainable agriculture. Plant protection chemicals are promising under high disease pressure. Phytoextracts are also gaining importance in plant disease management and are very cheap, eco-friendly compared to fungicides. Information on variability of pathogen has got greater significance in breeding for resistance against BLSB. In order to get a comprehensive idea about all the aspects mentioned above these investigations were carried out and the results thus obtained are discussed hereunder.

5.1 Survey for the severity of the disease

The present work was initiated with survey to know the severity and distribution of banded leaf and sheath blight of maize. Survey of farmers field in major maize growing regions of Northern Karnataka revealed that, BLSB severity varied from one locality to another, due to varied environmental conditions prevailing, cropping pattern and inoculum build up. The roving survey was therefore conducted to assess the disease severity to in Northern Karnataka. During *kharif* 2012 season maximum disease severity was observed in Uttarkannada district (51.10%), followed by Haveri district (34.30%). Minimum severity was noticed in Belgaum district (17.73 %). The highest BSLB severity was observed in Kalaghatagi taluka of Dharwad district (52.45%) followed by Mundgoad taluka of Uttarkannada district (51.54%). Lowest incidence was noticed in Bailhongal taluka of Belgaum district (10.75 %). Highest severity observed in red soil compare to black soil. The highest severity observed in irrigated area compare to rainfed area. DKC8101 hybrid recorded highest disease severity followed by CP818 whereas 900M recorded lowest disease severity. Maturity stage recorded highest disease severity whereas knee height stage recorded lowest.

The locations *viz.*, Kalaghatagi, Mundgoad, and Haveri were found severely affected by for BLSB. Environmental conditions, intensive cultivation of maize crop season after season, year after year, narrow genetic makeup of the commercial hybrids and non-adoption of disease management practices by the farmers could be a reason for higher incidence of disease in these areas of northern Karnataka.

5.2 Studies on variability of the pathogen

Studies on variability of *Rhizoctonia solani* f. sp. *sasakii* have a greater significance in breeding for resistance against BLSB. Studies on variability in the pathogen are important for documenting resistance source. Most of the composites and hybrids which are being grown on commercial scale are found to be more or less susceptible to BLSB. The reasons for lack of substantial durable resistance in the material may be attributed to presence of variability in the population (Saxena, 1997). In order to develop the disease resistant and high yielding cultivars, it is imperative to analyses and understands the variability in the pathogen.

In the present investigation, the infected leaves and leaf sheaths samples showing typical banded leaf and sheath blight symptoms were collected from six different locations. The pathogen was isolated and purified. Identification of isolates of the pathogen was made based on morphological characters.

These isolates of the pathogen were studied for morphological and cultural variability in isolates of pathogen character under identical condition and the results thus obtained are discussed hereunder.

5.2.1 Morphological studies

All the isolates under study showed differences in growth and colony characters. The considerable variation was observed among the various isolates tested. The variation in morphological characters of different isolates indicated that, growth of isolates *viz.*, Rsm5 and Rsm6 was excellent and isolates Rsm2, Rsm4 recorded good growth, and Rsm1 produced moderate growth, whereas poor growth was observed in Rsm3 isolates.

More sclerotia production was observed in isolate Rsm6 (115) followed by Rsm5 (105). Minimum sclerotia produced by isolate Rsm3 (54) followed by Rsm1 (80). Maximum size of sclerotia observed in Rsm6 (3.1 mm) followed by Rsm5 (2.5 mm). Largest size of sclerotia 3.1mm recorded in Rsm6 isolate followed by Rsm5 (2.5 mm), while the smallest size sclerotia of 1.87 mm was produced by Rsm4. Maximum isolate produced round shape sclerotia except Rsm5 and Rsm6 oval shape. Minimum time required for production of sclerotia was eight days in isolate Rsm6 and maximum time taken fifteen days by Rsm3. Maximum isolate produced circular peripheral sclerotia but Rsm1 and Rsm4 produced irregular. Maximum isolate produced brown to dark brown sclerotia. Growth of isolates *viz.*, Rsm5 and Rsm6 was excellent and isolates Rsm2 Rsm4 good growth, Rsm1 produced moderate growth, whereas poor growth was observed in Rsm3 isolates. Maximum radial growth was observed in the isolate Rsm5 and Rsm6 with colony diameter of 90.00 mm followed by Rsm4 (86.40 mm), whereas minimum colony diameter noticed in Rsm3 (79.33 mm). Maximum mycelium width was observed in Rsm5 (7.13 μ m) followed by Rsm6 (6.94 μ m), whereas minimum mycelium width was observed in Rsm3 (5.35 μ m). Maximum dry mycelium weight was observed in Rsm6 (565.00 mg) followed by Rsm6 (565.00 mg) followed by Rsm5 (532.00 mg), Rsm4 (494.00 mg) and Rsm1 (489.00 mg), whereas, minimum dry mycelium weight was observed in Rsm3 (206.00 mg). These results are in agreement with Srinivas *et al.* (2007) who collected ten isolates of *Rhizoctonia solani* f. sp. *sasakii* from major maize growing area of North India. They showed morphological variability with respect to colour of colony (reddish brown to dark brown), pattern of sclerotial production (peripheral and scattered), weight of sclerotia (1.05 - 1.71 mg) and number of sclerotial production (10-20). Similarly Akhtar *et al.* (2009) who collected five isolates from five different locations of Jharkhand, showed variation in their morphological characters such as colony colour (brown, black and white), colony growth (fast, slow and moderate), colony diameter (76.46 mm to 61.40 mm), sclerotial distribution (irregular to circular), size of sclerotia (micro to macro) and time taken for initiation of sclerotia production ranged from 7 days to 15 days. Similarly Hao (1994) who reported that sclerotial colour ranged from brown light to dark brown, black brown, chocolate brown, salmon and dark salmon. Size of sclerotial ranged from 0.85 to 3.05 mm.

5.3 Studies on efficacy of fungicides, botanicals and biocontrol agents

5.3.1 Efficacy of fungicides

In the absence of resistant cultivars, use of fungicides to control the disease is in practice, as it gives relief from the pathogen after the appearance of the disease. Hence, nine fungicides were evaluated under laboratory conditions.

Among the six systemic, four nonsystemic, six combiproduct fungicides and one antibiotic were tested, Propiconazole 25% EC, Carbendazim 50% WP, Carbendazim 12 %+ Mancozeb 63 % and Carbendazim 25 % + Iprodion 25 % gave 100 per cent mean mycelial inhibition at all their tested concentration. These results are in agreement with Jones *et al.* (1986) who reported that Propiconazole @5.2 X 10⁻² μ g a.i. ml⁻¹ very effective against *Rhizoctonia solani* in *in vitro* condition. Singh and Kaiser (1995) reported that Carbendazim was most effective chemical for *Rhizoctonia bataticola*. (Similar results have been observed by Ahuja and Payak (1986) Puzari *et al.* (1998) and Sharma and Rai (1999).

In the present study foliar spray with Propiconazole 25% EC, Carbendazim 50% WP, Carbendazim 12 %+ Mancozeb 63 % and Carbendazim 25 % + Iprodion 25% found effective in reducing the severity of banded leaf and sheath blight of maize.

5.3.2 Efficacy of botanicals

In recent years there has been increasing awareness on toxic hazards of chemicals to crop consumers and environment due to their residual and pollution effects. Generally systemic fungicides are used to control the phytopathogenic fungi. But extensive use of fungicides has become a major threat to the mankind. So, the importance of indigenous plant products in plant disease control has been emphasized. In the present study, investigations were carried out to evaluate different plant extracts for the possible presence of fungitoxic substances against *Rhizoctonia solani* f.sp. *sasakii* in laboratory conditions. It was evident from the study that *Azadirachta indica* (neem oil) at 10 per cent concentration showed significant inhibition of mycelial growth of *Rhizoctonia solani* f.sp. *sasakii*. These results are in conformity with Singh *et al.* (1980) who studied the fungitoxic properties of plant extract against *Rhizoctonia solani* and reported that *Azadirachta indica* suppress the formation of sclerotia of *Rhizoctonia solani* and inhibit growth of mycelium by 53.6 per cent under laboratory conditions. Similar results on antifungal activity of aqueous extracts of different plants have been reported by (Ark and Thompson, 1959).

Neem oil and neem seed kernel extract were found to be effective as growth inhibitors. *Jatropha* leaf extract and turmeric leaf extract was not at all inhibitory even at 10% concentration. In the present study, *Azadirachta indica* was very effective in inhibiting the growth of *Rhizoctonia solani* f.sp. *sasakii*. The inhibitory action of *Azadirachta indica* may be due to azadirachtin and monoterpenes which retards the growth and activation of the pathogen. (De Groot, 1972)

5.3.3 Efficacy of bioagents

As an alternative to fungicides, biological control can offer an alternate effective and environmentally safe management of banded leaf and sheath blight of maize. Nevertheless, a notable feature of biological control has been its freedom from harmful effects on man. In the present study, fungus *Trichoderma harzianum* was found to be superior over all other treatments with 65.13 per cent mycelial inhibition followed by *Pseudomonas fluorescens* (63.45 %), *Trichoderma viride* (63.19%) and *Trichoderma koningi* (62.35%). These results are in accordance with Meena *et al.* (2003) who reported that *Trichoderma harzianum* was effective in causing significant suppression of both, growth and sclerotial formation of *Rhizoctonia solani* f.sp. *sasakii*. *Trichoderma harzianum* caused 80 per cent inhibition of mycelial growth after 72 h of incubation, it also caused 35.5 per cent inhibition of sclerotial formation after 10 days of incubation. Similarly Biswas *et al.* (2008) who reported that, *Trichoderma harzianum* is reduced maximum mycelia growth by 42.7 per cent. Similarly Sharma *et al.* (2009) reported that, *Trichoderma spp.* in dual culture inhibited mycelial growth of *Rhizoctonia solani* significantly and inhibition from 89.5 to 62.5 per cent.

In the present study, *Trichoderma harzianum* and *Pseudomonas fluorescens* were found effective in inhibiting the growth of *Rhizoctonia solani* f.sp. *sasakii*. The antagonistic activity of the fungus may be due to toxin production by the fungus trichodermin and fast growing ability which retards the activation of the pathogen. The antagonistic activity of *Pseudomonas fluorescens* attributed due to production of secondary metabolites such as siderophores, antibiotics, volatile compounds, HCN, enzymes and phytohormones. *Pseudomonas fluorescens* enhance induce systemic resistance and act as PGPR (Sivakumar and Sharma, 2007).

5.4 Management of the disease

The results of the field trial conducted to know the efficacy of four seed dressing fungicides and two bioagents along with foliar spray eleven fungicides and two bioagents against banded leaf and sheath blight of maize indicated that seed treatment with seed treatment with *Pseudomonas fluorescens* @10 g kg⁻¹ of seed combined with two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS gave maximum grain yield (80.42 q ha⁻¹) over control (57.15 q ha⁻¹), stover yield (10.75 t ha⁻¹) over control (7.43 t ha⁻¹) and 100 seed weight (39.51 g) over control (22.84 g) with minimum PDI (20.40%) over control (65.60%).

Pseudomonas fluorescens @10 g kg⁻¹ of seed combined with two sprays of Hexaconazole 5 EC @ 0.1% and Carbendazim 50 WP @ 2.5 g kg⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% were the next best treatment and effectively. Seed treatment with *Pseudomonas fluorescens* @10 g l⁻¹ combined with two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS resulted increase the grain yield and stover yield to the tune of 40.72 % and 44.68% respectively with highest disease control efficacy (68.90%).

Seed treatment with *Pseudomonas fluorescens* @10g kg⁻¹ gave maximum grain yield (72.08 q ha⁻¹) over control (66.88 q ha⁻¹), stover yield (9.47 t ha⁻¹) over control (8.17 t ha⁻¹) and 100 seed weight (34.85 g) over control (28.15 g) with minimum PDI (32.84 %) over control (40.04%). Seed treatment with Carbendazim 50 WP @ 2.5 g kg⁻¹ and Carboxin 37.5 % + Thiram 37.5 % @ 2.5 g kg⁻¹ also gave well result to control of disease over control. *Pseudomonas fluorescens* @10 gkg⁻¹ recorded highest increase the grain yield and stover yield to the tune of 26.13% and 27.49% respectively with highest disease control efficacy (49.95%). These results are in accordance with Sivakumar and Sharma (2007) who reported that seed treatment with *P. fluorescens*@ 16 gkg⁻¹ of seed controlled effectively BLSB in maize. Similarly Meena *et al.* (2003) who observed reduction in disease incident of BLSB when *P. fluorescens* was used in seed and soil treatment and in foliar application. The antagonistic activity of *Pseudomonas fluorescens* attributed due to production of secondary metabolites such as siderophores, antibiotics, volatile compounds, HCN, enzymes and phytohormones. *Pseudomonas fluorescens* enhance induce systemic resistance and act as PGPR (Sivakumar and Sharma, 2007).

Foliar spray of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS gave maximum grain yield (78.01 q ha⁻¹) over control (59.94 q ha⁻¹), stover yield (10.10 t ha⁻¹) over control (8.08 t ha⁻¹) and 100 seed weight (36.66 g) over control (26.69 g) with minimum PDI (22.94%) over control (60.94%). Propiconazole 25 EC @ 0.1% recorded highest increase the grain yield and stover yield to the tune of 36.49 per cent and 35.94 per cent respectively with highest disease control efficacy (65.03%) followed by of Hexaconazole 5 EC @ 0.1%, Carbendazim 50 WP @ 0.1% and Carbendazim 12 % + Mancozeb 63 % @ 0.2%. These results are in accordance with Saxena (2002) who tested efficacy of chemicals *viz.*, Propiconazole, 0.1 per cent and Carbendazim, 0.05 per cent by applying as foliar sprays at 30, 40 and 50th day of planting, alone or in combinations. He observed Propiconazole @ 0.1 per cent was highly effective when the chemical was applied at initial stages at 30or 40day after planting and the second spray at 10 days after first. Similarly Akhtar *et al.* (2011) who proved Carbendazim (0.2 %) most effective as seed treatment showing 68.00 per cent reduction in disease over control and as a foliar spray (0.1%), it resulted least disease severity (25.78%) and highest grain yield (31.50 q/ha).

Future line of work

1. Further studies on molecular variability may be initiated.
2. Multi location trials may be conducted to test the efficacy of fungicide and bio-fungicides through integrated disease management approach to develop a model of IDM.
3. There is a need to identify resistance sources and hybrids and study the mechanism of resistance in resistant hybrids and inbred lines for disease resistance breeding.

SUMMARY AND CONCLUSIONS

The investigations on banded leaf and sheath blight of maize caused by *Rhizoctonia solani* f.sp. *sasakii* Exner include aspects viz., survey, variability study of pathogen (morphological and cultural), *in vitro* evaluation of fungicides, bioagents, botanicals and management of disease. The experiments were conducted during *Kharif* 2012, at Main Agricultural Research station, Saidapur Farm, Dharwad and Agricultural College, Department of Plant pathology, University of Agricultural Sciences, Dharwad. The results of the investigation are summarized hereunder.

The disease is widely distributed in Northern Karnataka. The disease appeared in severe form in Kalaghtagi (52.45%) followed by Mundgoad (51.54%). The lowest severity was noticed in Bailhongal (15.72 %) followed by Soudatti (12.57%). Maximum disease severity was observed in Uttarkannada district (51.10%) followed by Haveri district (34.30%). Minimum severity was noticed in Belgaum district (17.73 %). Highest severity observed in black soil of irrigated area in DKC8101 hybrid at maturity stage in Kalaghtagi taluka of Dharwad.

The variability studies carried out for six isolates collected from different places. Morphological and cultural characters of six isolates were studied under identical condition. Among six isolates isolate Rsm6 was found to be fast growing, maximum sclerotial size (3.1mm), oval shape and red brown sclerotia, minimum time took for initiation of sclerotial (8 days) and highest number of sclerotia per plate.

Among the six systemic, five non-systemic, six combiproduct fungicides and one antibiotic were tested *in vitro*, Propiconazole 25% EC, Carbendazim 50% WP, were found most effective followed by Carbendazim 12 % + Mancozeb 63 % and Carbendazim 25 % + Iprodion 25 %. Maximum inhibition of mycelial growth was recorded in *Azadirachta indica* at five and ten per cent concentration which was significantly superior to all other treatments followed by *Datura* seed extract.

Among the bioagents tested under laboratory conditions, *Trichoderma harzianum* gave maximum inhibition of mycelial growth, this was followed by *Pseudomonas fluorescens*, *Trichoderma viride* and *Trichoderma koningi*.

Studies on management of the disease revealed that, seed treatment with *Pseudomonas fluorescens* @10 g kg⁻¹ seed followed two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS found most effective treatment and resulted in lowest PDI. This treatment increased grain and fodder yield.

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STUDIES ON BANDED LEAF AND SHEATH BLIGHT OF MAIZE CAUSED BY *Rhizoctonia solani* f.sp. *sasakii* EXNER

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2013

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ABSTRACT

Banded leaf and sheath blight of maize caused by *Rhizoctonia solani* f.sp. *sasakii* Exner is an important disease which results in heavy yield loss. The investigations include main aspects viz., survey, variability of pathogen, *in vitro* evaluation of fungicides, bioagents, botanicals and management of the disease. The results of the investigations are summarized hereunder

The roving survey on the disease severity revealed that, maximum disease severity was observed in Kalaghtagi (52.45%) followed by Mundgod (51.54%). Minimum severity was noticed in Bailhongal (15.72%). Highest disease severity observed in black soil under irrigated area on DKC 8101 hybrid in Kalaghtagi taluka of Dharwad district. Six isolates collected from different part of Northern Karnataka were studied for their variability. The isolates showed variability in morphological and cultural characters. Among six isolates, isolate Rsm6 (Kalaghatagi) was found to be fast growing, maximum sclerotial size (3.1mm), oval shape and red brown sclerotia, minimum time took for initiation of sclerotial production (8 days) and highest number of sclerotia per plate (115).

The *in vitro* studies on fungicides evaluation at various concentration, indicated Propiconazole 25% EC and Carbendazim 50% WP were found most effective in inhibiting the growth of the fungus. The plant extracts viz., nimbidine and NSKE at 5 and 10 per cent concentrations were effective against the pathogen. Among the biocontrol agents evaluated, *Trichoderma harzianum* found effective against the pathogen. Field studies on the management of the disease revealed that, seed treatment with *Pseudomonas fluorescens* @10 g kg⁻¹ seed followed by two sprays of Propiconazole 25 EC @ 0.1% at 30 and 40 DAS found most effective treatment and resulted in lowest PDI (20.40%). This treatment increased grain yield (40.72%) and fodder yield (44.68%) over untreated check.