

CURVULARIA LEAF SPOT OF MAIZE AND ITS INTEGRATED MANAGEMENT

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By

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1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in the world and ranks third next to wheat and rice. It is grown throughout the world under a wide range of climatic conditions. Since pre-Hispanic time, it has been the basic food for the majority of the people in Mexico, Central America and Latin America. Maize was introduced to India from America at the beginning of 17th century. In addition to staple food for human being and quality feed for animals, it serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries *etc.* In the last one decade, it has registered the highest growth rate among all food grains including wheat and rice because of newly emerging food habits as well as enhanced industrial requirements.

Maize suitability to diverse environments is unmatched by any crop as the expansion of maize to new areas and environment still continues, as it has a range of plasticity. It is grown from latitude 58°N to 40°S, from sea level to higher than 3000 m altitude and in areas receiving yearly rainfall of 250 to 5000 mm (Downsell *et al.*, 1996).

Maize is one of the staple food crops and widely cultivated crop throughout the world. The United States produces almost half of the world's production; other top producing countries are China, Brazil, France, Indonesia and South Africa. Maize is a unique crop that expands its adaptation from very high north and south latitudes in temperate areas, through subtropical and tropical environments in north and south of the equator.

In India, it is cultivated both as food and fodder crop. It has got immense potential and hence called as 'Miracle crop' and also called as 'Queen of cereals'. In the future, maize demand is expected to increase, mainly because it is used by larger population as human food and due to its increased consumption as feed in poultry for animal protein. Besides multiple uses contribute to diet diversification and improved nutrition in human

beings through exploitation of quality protein maize (Singhal, 2003). Every part of the maize plant has economical value: the grain, leaves, stalks, tassel and cob can all be used to produce a large variety of food and non food products (Akobundu and Agyakwa, 1987). Due to the growing demand for dairy and meat products in developing countries and the decline in rice production in China and India.

Globally maize occupies an area of 174.2 m ha with the production of 852 m t and productivity accounts for 4890 kg ha⁻¹. In India, the maize occupies an area of 9.42 m ha with the production of 22.26 m t and average productivity of 2583 kg ha⁻¹. In Karnataka maize occupies an area of 1.38 m ha, with the production of 4.00 m t and average productivity is 2883 kg ha⁻¹ (Anon., 2014a).

In India, maize is the third most important cereal crop after rice and wheat that serves as a source of raw material for developing hundreds of industrial products (Anon., 2007). Maize kernel contains about 77 per cent starch, two per cent sugar, nine per cent protein, two per cent ash on a water free basis, five per cent pentosan and five per cent oil. It has more than 1000 industrial uses and mainly used for production of starch due to its high starch content of 77 per cent. Maize seed oil contains the highest polyunsaturated fatty acids (PUFA), linoleic acid (61.99%) and it remains as liquid at fairly low temperature which is helpful in combating heart disease. Maize seed oil is also low in linolenic acid (0.7%) and contains a high level of natural flavor.

It is mainly cultivated in the states of Andhra Pradesh, Karnataka, Bihar, Rajasthan, Madhya Pradesh, Gujarat, Chhattisgarh, Maharashtra, Tamil Nadu and Uttar Pradesh. It is also widely believed that, in the very near future maize may become a staple food for human consumption if the demand for rice and wheat is not fulfilled through increased production. It is mainly grown in the districts of Bagalkot, Belagavi, Dharwad, Gadag, Haveri, Bellary, Mysore, Chitradurga and Shimoga districts.

Maize is being plagued by an array of diseases which include the leaf spot of maize caused by *Curvularia lunata* (Wakker) Boed, exhibiting symptoms as small chlorotic spots

which gradually expand into round or oval shaped lesion surrounded by a wide translucent straw yellow halo (Singh *et al.*, 2002). It is an important seed and soil borne disease prevalent in the hot, humid maize areas. The disease produces small necrotic or chlorotic spot with a light colored halo; lesions are about 0.5 cm per spot when fully developed and this cause significant damage to maize up to 60 per cent due to greater loss in photosynthetic area of the crop (Hai *et al.*, 1995, Huang *et al.*, 2004 and Hua *et al.*, 2006), and in maize growing areas, *Curvularia* leaf spot is more prevalent in hot and humid conditions (Shurtleff., 1980). Farr *et al.* (1989) reported its appearance on a wide variety of plants, including *Zea* in the USA. It is recorded on maize and a wide range of other plants in Australia (Anon., 1998). In 1996, the disease broke out in Northeast China and resulted in a great grain loss of 260 million kilograms. The disease was widely spread to more than 10 provinces nationwide over the last two decades (Huang *et al.*, 2009). The yield loss determination of maize *Curvularia* leaf spot showed significant correlation between yield loss and corn varieties or *Curvularia* strains. The range of corn yield loss was 10.10 to 48.62%. The major components of yield loss includes shorter and thinner ear, number of grains per ear and 100 grain weight. The loss rate of 100 seed weight was about two times higher than that of seed number per ear (**Yan *et al.*, 2003**).

In India new leaf spot disease of maize incited by *Curvularia clavata* Jain has been reported from Varanasi region (Mandokhot and Basu Chaudhary, 1972). It was reported to cause a yield loss up to 60 per cent under inoculated conditions (Grewal and Payak, 1976). The disease incidence was recorded from four places in Uttarakhand. It was recorded in severe condition from Haridwar and Dehradun whereas from Kashipur and Haldwani it was recorded in moderate to traces. Extensive survey conducted in Rajasthan during *kharif* 2010 revealed that the incidence of *C. lunata* was in severe to moderate in villages like Lohira, Kavita, Iswal, Ghiyara and Baswara. Disease incidence was high in Rajasthan area due to high rain fall and high humidity (Anon., 2011).

Presently little information is available on maize Curvularia leaf spot disease in Karnataka. Keeping this in view, the present investigation was under taken with the following objectives.

OBJECTIVES

- Roving survey to identify the hot spots for maize Curvularia leaf spot in northern parts of Karnataka.
- Loss assessment in popular public and private maize hybrids due to the disease.
- Integrated management of the disease.

2. REVIEW OF LITERATURE

Curvularia leaf spot (CLS) caused by *Curvularia lunata* (Wakk.) Boedijn, is the important disease in maize (Wang *et al.*, 2006; Khalil *et al.*, 2010). In India, the disease is reported in almost all the maize growing areas.

Literature with regard to symptoms, distribution, disease development, chemical control and resistant sources is available in limited quantum. However, information on loss assessment and integrated disease management aspects is very meager. Hence, the present investigation aims at systematic laboratory and field level studies on management of Curvularia leaf of maize and the literature with respect to these aspects are presented here under.

2.1 Symptomatology

The disease starts at first as small chlorotic spots which gradually expand into round or oval shaped lesion surrounded by a wide translucent straw yellow halo. A number of lesions can be connected leading to the formation of leaf necrosis (Dai *et al.*, 1995, Li *et al.*, 2006).

2.2 Geographical distribution and economic importance

Curvularia leaf spot distributed in Australia, India, Indonesia, Malawi, Nepal, Nigeria, Pakistan, Continental United States, Hawaii and Zimbabwe (Raabe *et al.*, 1981).

CLS is prevalent in hot and humid maize growing areas and can damage crops significantly (Shurtleff, 1980). It has been recorded on maize and a wide range of other plants in Australia (Anon., 1998). Survey on leaf diseases of maize in the south western Nigeria showed that occurrence of other maize leaf diseases such as leaf rust (*Puccinia polysora*), leaf spots (*Curvularia lunata*) and ear rot (*Fusarium moniliforme*) are on the increase (Olakojo and Iken, 1999).

The yield loss determination of maize CLS showed significant correlation between yield loss and corn varieties or Curvularia strains. There were different effects on corn

yield loss that same strain to different corn varieties or different strains to same corn variety. The range of corn yield loss was 10.10 to 48.62 per cent. This disease influenced the factors of corn yield constitution, the ear became shorter and thinner, the hundred-grain weight reduced, significant effects on the number of seeds per ear and of 100 grain weight (Yan *et al.*, 2003).

In India leaf spot disease of maize incited by *Curvularia clavata* Jain has been reported from Varanasi region (Mandokhot and Basu Chaudhary 1972). It was reported to cause an yield loss up to 60 per cent under inoculated conditions (Grewal and Payak, 1976). The disease incidence was recorded from four places in Uttarakhand. It was recorded in severe condition from Haridwar and Dehradun whereas from Kashipur and Haldwani it was recorded in moderate to traces. Extensive survey conducted in Rajasthan during *kharif* 2010 revealed that the incidence of *C. lunata* was in severe to moderate in villages like Lohira, Kavita, Iswal, Ghiyara and Baswara. Disease incidence was high in Rajasthan area due to high rain fall and high humidity (Anon., 2011).

Harlapur (2014) conducted survey during *kharif*, *rabi* and summer by random field visits. *Curvularia* leaf spot and ear rot were pronominally prevalent in heavy rainfall and transitional zone. High severity of *Curvularia* leaf spot was noticed in Kalaghatagi and Dharwad taluks of Dharwad district and also in Davanagere and Haveri districts.

2.3 *In vitro* evaluation of fungicides, commercially available botanicals and indigenous technology knowledge against *Curvularia lunata*

2.3.1 *In vitro* evaluation of plant extracts

Plant metabolites and plant based pesticides appear to be one of the better alternatives as they are known to have minimal environment impact and danger to consumers in contrast to the synthetic pesticides. Active principles from medicinal plants are being tried as replacements of synthetic fungicides in management of plant diseases in organic farming system.

Plant derivatives possessing pesticidal properties are evoking worldwide interest as an alternative or as supplements for the existing pesticides for several reasons (Toriyama, 1972). Integration of chemicals, plant extracts, and biotic agents along with resistance for managing plant diseases has considered as a novel approach (Papavizas, 1973).

Mishra and Dixit (1978) found antifungal activity in 21 angiosperms against *Puccinia recondita* Rob. ex Desm. on wheat. Shekhawat and Prasad (1971) reported that out of nine plant extracts tested viz., *Allium cepa* L., *Allium sativum* L., *Ocimum sanctum* L., *Mentha piperita* L. and *Beta vulgaris* L. showed strong inhibitory action against *Alternaria tenuis* Nees. from bean, *Helminthosporium* sp. from watermelon and *Curvularia penniseti* (Mitra) Boed. from bajra.

Bhowmick and Vardhan (1981) reported the antifungal activity in many of the plants extracts against *C. lunata*. Extracts of two plants i.e., *Cinnamomum comphora* L. and *Catharanthus roseous* L., inhibited growth and sporulation of the test fungus.

Usman *et al.* (1991) in their field trial with neem products, viz., neem oil, neem seed kernel extract and neem cake extract, found that neem seed kernel extract (2%) was most effective in controlling rust and late leaf spot of groundnut and gave the maximum yield.

Many researchers showed the antifungal activity of neem based products both under *in vitro* and *in vivo* condition against many of the plant pathogenic fungi (Adiver *et al.*, 1995, Hundekar, 1999 and Njoku *et al.*, 2000).

According to Serah (2000) leaf extracts of *Azadirchta indica* L, *Chromolauea odorata* L. and *Ocimum sanctum* L., were very effective against *Curvularia. pallescens*.

Omagbemi *et al.* (2001) observed the effectiveness of leaf extracts of *Acalypha wilkesiana*, *Vernoniaamygda* line and *Chroinolaena odorata* in inhibiting growth and sporulation of *C. lunata*, cause of leaf spot disease in maize.

Ramesh *et al.* (2003) reported that maximum inhibition of spore germination of *Colletotrichum gloeosporioides* Penz. was observed in garlic bulb extract at 10 per cent concentration (72.81%) followed by tulasi leaf extract at the same concentration (55.57%). Plant extracts have unique antimicrobial properties, which act in holistic mode. Various workers have reported that plant extracts and their secondary metabolites; alkaloids, terpenoid, glycosides and phenolic acids have a number of medicinal properties and affect biological functions at very low concentrations; some of them also possess antimicrobial activity (Gurjar *et al.*, 2012).

Sanjivareddi (2012) tested seven commercially available botanicals against *Erysiphe cichoracearum* DC f. sp. *helianthi* Jacz at 0.25 per cent, 0.5 per cent, 0.75 per cent and 1 per cent concentration. Maximum inhibition of conidial germination of 66.56 per cent and 73.23 per cent was noticed in soldier at 0.25 per cent and 0.75 per cent concentrations respectively. Further, Nagaraja (2013) also tested five botanicals against *Puccinia substriata* var *indica* Ramachar and Cummins at 0.25 per cent, 0.5 per cent, 0.75 per cent and 1 per cent concentration. He observed maximum inhibition in neem oil at 0.25 per cent. (81.74%) followed by soldier (79.90%) at 0.25 per cent.

Bisht *et al.* (2013) observed significant difference among the different plant extracts evaluated *in vitro* against inhibition of mycelial growth of *C. lunata*. Amongst the plant extracts, lantana was highly effective @ 15 per cent (86.76 inhibition %) and 20 per cent (89.49 inhibition %) followed by morphantki @ 5 per cent (83.53 %) and 10 per cent (85.88 %), respectively. The mycelial growth inhibition rate was increased with increase in the plants extracts concentrations.

2.3.2 Chemical fungicides

Attempts have been made to control CLS of maize by chemicals. *In vitro* tests have been used to test the effectiveness of chemicals.

Mandokhot and Basu Chaudhary (1972) reported that the hexaferb, hexathir, difolatan 80WP, ziram, dithane Z-78, dithane M-45, captan, miltox, blue copper-50 and zincop at of different concentrations inhibited the spore germination. Spore germination percentage was decreased with the increase in fungicide concentration. The lowest concentration required to inhibit complete spore germination was 9 ppm of difolatan 80WP while highest was of miltox (800ppm). Rests of the fungicides were effective between these extremes.

Serah (2000) reported that ridomil completely inhibited mycelial growth of *C. lunata* at 0.2 and 0.25 per cent concentration.

Dithane-M 45, a synthetic fungicide performed significantly superior in the control of *C.lunata* (Njoku *et al.*, 2000 and Yan *et al.*, 2003).

Sumangala *et al.* (2008) reported that *in vitro* evaluation of four systemic fungicides the maximum inhibition of mycelial growth of *C. lunata* was obtained from difenoconazole (98.80%) and propiconazole (98.10%) at 0.1 per cent concentration. Among the three non-systemic fungicides tested, mancozeb (98.80%) was found most effective followed by chlorothalonil (63.67%) at 0.2 per cent concentration. When the seeds were treated with fungicides, mancozeb gave the highest seed germination (99.36%) and vigour index (1253.3) followed by difenoconazole with germination and vigour index of 94.88 per cent and 1232.4 respectively.

Yadav and Ratnoo (2014) studied the comparative efficacy as foliar spray for controlling the Curvularia leaf spot in cotton, among five chemicals, mancozeb (0.2%) showed 94.12 per cent inhibition of mycelial growth.

2.3.3 Indigenous technology knowledge (ITK's)

In India, it is believed that the cow dung and urine wash away the sin of one's father and it was attributed for purifying qualities (King *et al.*, 1954). Because of the inherent hazardous effects involved in conventional chemical management, the alternative plant protection measures like organic farming, use of FYM, green manuring, neem oil, botanicals and animal by-products such as cow urine, buttermilk as described in Vedas, Arthashastra, Agnipuran, Surapala's (Nene, 2003; Sadhale, 1996 and Wojtilla, 1985) etc., are gaining importance.

Padmodaya (1994) reported the inhibitory effect of mahapanchagavya (MPG) on tomato wilt pathogen under *in vitro* condition and showed superior to carbendazim in reducing *Fusarium* wilt of tomato and increasing the vigor of plant and yield.

Jayashree *et al.* (1999) observed that plant derivatives, neem oil and thuja 30 per cent inhibited the pumpkin yellow vein mosaic virus effectively. The only product tested was buttermilk, which found to reduce virus transmission effectively.

Spraying of half liter of milk mixed in 4.5 liters of water spray at weekly intervals as a preventive control measure against mildew, mosaic virus and blights (Stoll, 2000).

Jahagirdar *et al.* (2000) conducted field experiment and investigated eco-friendly integrated management of pepper foot rot caused by *Phytophthora capsici* Leonian and observed that combined application of *Trichoderma viride* Pers. and modified panchagavya (MPG-3) was reduced the disease incidence and increased the yield above 50 per cent when compared to control.

Selvi and Kurucheva (2005) evaluated the effect of natural products like sheep urine at five per cent, buffalo urine at 20 per cent, hen litter and goat dung at 100 per cent. Results indicated that hen litter reduced the production of poly galacturonase (PG) up to 88.61 per cent, polygalacturonase trans-eliminase (PGTE) with 90.83 and pectin trans-eliminase (PTE) with 83.63 per cent than the other products tested.

Priya and Kurucheve (2005) studied the effect of animal excretes on the conidial germination of *Cercospora personata* (Berk. and Curt.) Ell. and Eve. Among the animal excretes tested cow urine at 10 per cent, cow dung at 20 per cent and cow urine plus cow dung (1:1) at 2.5 per cent concentration recorded complete inhibition of conidial germination. In control, maximum conidial germination of 96.0 per cent was recorded.

Sapre and Verma (2006) reported that cow urine and buttermilk reduced the mycelia growth, number and size of sclerotia of *Rhizoctonia bataticola* (Taub.) Butler. The mycelial growth was completely inhibited by buttermilk at 500 and 1000 ppm whereas, at 100 ppm it was least (3.31 mm). Cow urine and buttermilk not only reduced the mycelial growth of *S. rolfsii* but also affected the viability of sclerotia formed and reduced number of sclerotia per plate. Smallest sclerotia were recorded in buttermilk followed by cow urine, slight reduction in mycelial growth of *Fusarium solani* f. sp. *glycine* by cow urine and butter milk. Conidial production decreased with increasing concentration of cow urine.

Panchagavya - an organic formulation evaluated *in vitro* for its antifungal activity against *C. lunata* in rice, which found to be the dominant pathogen in causing grain discolouration. Panchagavya resulted in 86.30 per cent inhibition of mycelial growth and 95.9 per cent of spore germination of *C. lunata*. Seed treatment with panchagavya further enhanced the seed germination with 90.7 per cent and vigor index of 1036 (Sumangala and Patil, 2007).

Hurali (2008) tested different ITK's against uredospore germination of *Phakopsora pachyrhizi* Syd. and observed that cow urine recorded maximum per cent inhibition of uredospore germination over control at 1:2 dilution. However, cow urine at 1:2 dilution found on par with its 1:5 and 1:10 dilutions followed by cow milk and buttermilk treatments.

Sanjivareddi (2012) tested different ITK's against inhibition of conidial germination of *E. cichoracearum* f.sp. *helianthi* (powdery mildew of sunflower) at different

concentrations. At 30 per cent concentration panchagavya (70.75%) was superior followed by cow urine (67.75%).

Nagaraja (2013) observed that at 30 per cent concentration cow urine had maximum inhibition of uredospores germination of *P. substriata* var *indica* (89.03%) followed by cow milk (87.39%) and panchagavya (83.84%).

2.4 Integrated management of the disease

The possibilities of controlling plant diseases by the integration of several methods have been the subject of extensive research. Integration of chemicals, plant extracts, ITK's, plant based products and chemical fungicide for managing plant diseases is considered to be a novel approach. The literature on integrated management of *Curvularia* leaf spot of maize is lacking. Therefore, reviews pertinent to *Curvularia* leaf spot and other diseases of different crops have been reviewed and given below.

Shivashankar and Kadam (1993) reported that spraying of neem leaf extract (2%) in combination with recommended fungicides recorded numerical superiority in reducing leaf spot and rust incidence in groundnut.

Patil (1996) reported that, the addition of neem seed kernel and/or amaranthus leaf extracts in the spraying schedule along with propiconazole found to be effective in reducing the severity of sunflower rust at all the stages of crop growth. AUDPC values were less in the plant extracts applied plots compared to control. When the fungicide applied with the plant extract in sequence, the disease severity and AUDPC values were more or less on par with the fungicide application alone. Maximum B:C obtained in propiconazole-amaranthus-propiconazole (1:3.02) followed by propiconazole-nimbidine-propiconazole (1:0.80) spray schedule.

Anahosur *et al.* (2000) observed that use of nimbidine (0.5%) inter mixed with hexaconazole (0.1%) sprays reduced the disease of soybean rust index and thereby increase the yield.

Basak and Lee (2002) reported that cow urine found inhibitory to the mycelial growth of *Fusarium oxysporum* f. sp. *cucumerinum*, *F. solani* f. sp. *cucurbitae* and *Sclerotinia sclerotiorum* (Lib.) that cause diseases in cucumber. Also reported positive response of fresh cow urine and cow dung in suppression of mycelial growth of *F. solani*, *F. oxysporum* and *S. sclerotiorum*.

Gurudatt *et al.* (2003) reported that addition of nimbiocidine in the spray schedule along with hexaconazole, propiconazole and triadimefon were found effective in reducing the soybean rust severity with increasing seed yield, 100 seed weight and B: C. Further Hurali (2008) conducted the experiment on field evaluation of ITK's, plant and protein based products and chemical fungicides against rust of soybean and observed that cumulative sprays of hexaconazole @ 0.1 per cent recorded lower disease index followed by cristol 56SL @ 1 per cent- hexaconazole @ 0.1 per cent- cristol 56SL @ 1 per cent and cow milk @ 10 per cent - hexaconazole @ 0.1 per cent - cow milk @ 10 per cent treatments. Whereas, seed yield was concerned, neem oil @ 1per cent- hexaconazole @ 0.1 per cent - neem oil @ 1 per cent recorded the maximum followed by hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent and cow milk @ 10 per cent - hexaconazole @ 0.1 per cent - cow milk @ 10 per cent. As for as hundred seed weight was concerned, hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent treatment recorded maximum, which was found on par with remaining treatments except control.

Sanjivareddi (2012) studied on integrated management of powdery mildew of sunflower and found that spraying of wettable sulphur @ 0.3 per cent followed by cow urine @ 20 per cent gave better control.

Nagaraja (2013) conducted the experiment on field evaluation of ITK's, plant based products and chemical fungicides alone and their combinations against rust of bajra and reported that the spray schedule hexaconazole @ 0.1 per cent- hexaconazole @ 0.1 per cent (67.33%) and neem oil @ 1.0 per cent- hexaconazole @ 0.1 per cent (51.95%) was found best in reducing the rust severity and increasing the grain yield.

Patil and Basavaraj (2014) reported that spray schedule of cow milk @ 10 per cent-hexaconazole @ 0.1 per cent-cow milk @ 10 per cent, cristol 56SL @ 1.0 per cent-hexaconazole @ 0.1 per cent- cristol56SL @ 1.0 per cent and neem oil 1.0 per cent-hexaconazole @ 0.1 per cent- neem oil 1.0 per cent at 15 days of interval were found best in reducing rust intensity and increasing grain yields of soybean.

2.5 Screening of maize genotypes to Curvularia leaf spot

Among the 35 inbreds, five viz., EI-460, EI-585, EI-582, EI-586-1 and LM-10 exhibited resistant reaction, while six entries (CML-370, EI-561, EI-470, EI-497-1, EH-1561, EC-3135) showed moderately reaction, 14 were susceptible while the remaining entries were highly susceptible to Curvularia leaf spot (Choudhary *et al.*, 2011).

113 elite maize lines were evaluated against major foliar diseases under field by artificially inoculated epiphytotic conditions during *kharif* 2010-12 and it was yielded 77 lines having resistant to moderately resistant reaction to one or more foliar diseases. Two lines viz., WIN POP-3 and HKI 1040-5 have shown resistant reaction to Curvularia leaf spot (Anon., 2013).

A total of 120 late maturing maize genotypes were screened. Among them 59 genotypes showed reaction resistant to moderately resistant to Curvularia leaf spot. These evaluated against different foliar disease. The screenings of these genotypes were carried out under artificially inoculated conditions in the various hot spots located in different agro climatic zones of the country during *kharif* 2013 (Anon., 2014b).

3. MATERIAL AND METHODS

Present investigation was carried out during the period 2013-15. Laboratory experiments were carried out in the Department of Plant Pathology, College of Agriculture, Vijayapur, University of Agricultural Sciences, Dharwad, Karnataka. Field experiments were taken up at Agricultural Research Station, Arabhavi, University of Agricultural Sciences, Dharwad, Karnataka.

Glassware and Cleaning

In all the experimental studies Borosil glassware's were used. The glassware were kept in the cleaning solution for 24 hr containing 60 g of potassium dichromate ($K_2Cr_2O_7$), 60 ml of concentrated sulphuric acid (H_2SO_4) in 100 ml of water. Then, they were washed with soap powder followed by cleaning in tap water.

Sterilization

All the glassware were sterilized in an autoclave at 1.1 kg/cm^2 pressure for 15 min and then kept in hot air oven at 55°C for one hour. The solid media was sterilized at $1.1\text{-}1.4 \text{ kg/cm}^2$ pressure for 10- 15 min.

3.1 Roving survey of the disease in Belagavi, Bagalkot and Vijayapur districts of northern Karnataka

Intensive roving survey was carried out in three districts (Belagavi, Bagalkot and Vijayapur) of north Karnataka, during October - November 2014. The maize fields on the survey route were visited and the observations on Curvularia leaf spot (CLS) severity, stage of the crop and the condition under which the crop was grown (rainfed or irrigated) was noted down.

The severity of Curvularia leaf spot disease was recorded by using 0 - 9 scale of Mayee and Datar (1986).

Scale:

Rating value	Description
0	No symptoms on the leaf.
1	Up to 1% of leaf area covered with leaf spots
3	1-10% of leaf area covered with leaf spots.
5	11-25% of leaf area covered with leaf spots.
7	26-50% of leaf area covered with leaf spots
9	More than 50% of leaf area covered with leaf spots

Further, these scales were converted to per cent disease index (PDI) using the formula given by Wheeler (1969).

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of the individual disease ratings}}{\text{Number of leaves assessed} \times \text{Maximum grade}} \times 100$$

3.2 Sample collection and isolation of the pathogen

Maize leaves infected by *Curvularia lunata* with typical round or oval shaped lesion surrounded by a wide translucent straw yellow halo showing leaf samples were collected from the farmers field nearer to College of Agriculture, Vijayapur during *kharif* 2013. The pathogen was isolated following standard tissue isolation technique as mentioned below.

The infected leaf bits along with some healthy portions were surface sterilized in 1:1000 mercuric chloride solution for 30 sec and washed thoroughly thrice in sterilized distilled water to remove the traces of mercuric chloride, if any. Then such bits were aseptically transferred to sterilized Potato Dextrose Agar (PDA) Petridishes. The Petridishes were incubated at room temperature ($28 \pm 1^\circ\text{C}$) and observed periodically for fungal growth. The pure colonies which developed from the bits were transferred to PDA slants and incubated at room temperature for 10 days.

3.2.1 Single spore isolation

This method was followed for maintaining pure culture, as this fungus is multi-celled and known for heterokaryotic in nature. Dilute spore suspension (8-10 spores/ml) was prepared in sterile distilled water and one ml of such suspension was spread uniformly on two per cent water agar plates before its solidification. Single spore was marked with the ink and was allowed to germinate. Such plates were incubated at $28\pm 1^{\circ}\text{C}$ and periodically observed for germination of spores. Hyphal initials/threads emerging from each end cell of the single spore was traced and marked with the ink. Then tip of the hyphae was cut with sterile cork borer and transferred to the PDA slants and incubated at $28 \pm 1^{\circ}\text{C}$ for 10 days. Thus obtained culture was used for further studies.

3.2.2 Maintenance of the culture

The fungus was sub cultured on PDA slants and kept at $28\pm 1^{\circ}\text{C}$ for 10 days and such slants were preserved in refrigerator at 5°C and renewed once in 30 days.

3.2.3 Proving the pathogenicity

The *C. lunata* was multiplied in potato dextrose broth. Ten days old fungal growth was homogenized in sterilized warring blender with sterilized distilled water and was filtered through muslin cloth. The spore suspension along with mycelial bits were sprayed with atomizer on 20 days old maize plants of the hybrid Dekalb grown in earthen pots (50 × 30). The inoculated plants were then covered with polythene hoods for 48 hr to create high humidity. Plants of same aged sprayed with sterilized water served as control. Observations were made at regular intervals for the development of symptoms. The fungus was reisolated from infected leaves and the culture obtained was compared with the original culture to confirm the identify.

3.3 Loss assessment in maize genotypes due to Curvularia leaf spot.

Field experiment was carried out at Agriculture Research Station, Arabhavi, University of Agricultural Sciences, Dharwad during *kharif* 2014-15 to assess the losses

due to CLS in fifteen popular maize genotypes. Hexaconazole @0.1 per cent was sprayed at regular interval for protecting the fifteen genotypes with leaf spot infection. Unsprayed genotypes block were treated as unprotected treatment. Details of the experiment are given as below.

Design : Split plot

Treatments : a) Main plot: Two: M₁- Fungicidal sprayed (Protected),

M₂- Fungicidal unsprayed (Unprotected)

b) Sub plot: 15 Genotypes (CP 818, CP 808, NK 6240, 900M Gold, Prabal, Super 900M, Pinnacle, DKC 9133, All rounder, Shimsha 517, Kaveri 244, Mograon, Arjun, GH 0727 and MAH 957).

Replications : Two

Plot size : Main plot: 18m x 4m

Sub plot 1.8m x 4m (Three rows of 4m length)

Spacing : 60 x 20 cm

The inoculum of *C. lunata* was mass multiplied on potato dextrose broth (Plate 1), it was sprayed twice to the unprotected block at alternate days in the evening hours 20 days after sowing create high disease pressure. Observations on leaf spot severity in different treatments were taken at physiological maturity.

3.3.1 Observations recorded

a. Disease severity

In each treatment ten plants were randomly selected and CLS severity was recorded when the crop attained physiological maturity by following 0-9 scale of Mayee and Datar (1986) and further scales were converted to per cent disease index (PDI) using the formula of Wheeler (1969) as described earlier.



Plate 1: Mass multiplication of *C. lunata* inoculum on potato dextrose broth

b. Grain yield (Kg)

Grain yield per plot was recorded by harvesting each treatment separately. Further grain yield per plot was converted to grain yield per hectare.

c. Grain weight (g)

One hundred grains were randomly collected from threshed seeds of each treatment and weight was recorded using an electronic balance.

d. Stover yield (Kg)

Stover yield per plot was recorded by harvesting each treatment separately. Further stover yield per plot was converted to stover yield per hectare.

e. Oil content (%)

The oil content in grains of each treatment was estimated with the help of 20 Pi Minispec Nuclear Magnetic Resonance (NMR) spectrometer installed at All India Coordinated Research Project on sunflower, Main Agriculture Research Station, University of Agricultural Sciences, Raichur.

f. Starch content (%)

The starch content in grains of each treatment was estimated with the help of NMR multigrain analyzer and expressed in percentage. Nuclear Magnetic Resonance (NMR) unit at Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur.

3.4 Integrated management of *Curvularia* leaf spot

3.4.1 *In vitro* evaluation of fungicides, commercially available botanicals and indigenous technology knowledge against *Curvularia lunata*

3.4.1.1 *In vitro* evaluation of fungicides

Ten fungicides consisting of six systemic and four non systemic were assayed by following poisoned food technique (Zentmeyer,1955) for their efficacy against *C. lunata*

for inhibition of radial growth on the potato dextrose agar (PDA) media under *in vitro* condition. The systemic fungicides were tested at 0.025, 0.05 and 0.1 per cent concentration, whereas non-systemic fungicides were tested at 0.1, 0.2 and 0.3 per cent concentration. Required quantity of individual fungicide was added separately into molten and cooled potato dextrose agar so to get the described concentration. Later 20 ml of the poisoned medium was poured into flat bottomed sterile Petri plates. The plates were then inoculated by cutting half cm of 10 day old mycelial mat of *C. lunata* and incubated at $28 \pm 1^{\circ}\text{C}$. Three replications were maintained for each treatment. The fungus grown on the PDA agar medium without any fungicides served as control. The radial growth of the colony was recorded when maximum growth in control plates was noticed and photographs were taken. The per cent inhibition of the mycelial growth of the fungus was determined by using the following formula (Vincent, 1947).

$$I = \frac{C - T}{C} \times 100$$

Where,

I= Per cent inhibition

C= Radial growth in control

T= Radial growth in treatment (fungicide/ botanicals)

The details of the fungicides evaluated are furnished hereunder.

Systemic fungicides

Sl. No	Common name	IUPAC* name	Trade Name
1	Carbendazim	Methyl-2-benzimidazole carbamate	Bavistin 50%WP
2	Difenconazole	Cis, trans-3-chloro-4 (4-methyl-2(1H-1,2,4-triazole-1-yl methyl)1,3 dioxalan-2yl) phenyl, 4-chlorophenylether	Score 25% EC
3	Hexaconazole	(RS)-2-(2,4-dichlorophenyl)-1(H-1, 2,4-triazol-1-yl) hexan-2-0l)	Contaf 5% EC
4	Propiconazole	1-(2,4-dichlorophenyl) 4 propyl-1-3-dioxalan-2-methyl) H-1, 4-triazole)	Tilt 25% EC
5	Thiophanate methyl	1,2-bis-(3-ethoxy carboxy 1-2-thioureda) Benzene	Topsin-M 70 %WP
6	Triadimefon	1 (4 chlorophenoxy)-3-3 dimethyl-1-(1H-1, 2,4-triazole-1 Y)-butanone	Bayletan 25% WP

Non systemic fungicides

Sl. No	Common name	IUPAC* name	Trade Name
1	Chlorothalonil	2,4,5,6-tetrachloroisophthalonitrile	Kavach 75% WP
2	Mancozeb	Manganese zinc ethylene bis dithiocarbamate	Indofil M-45 75% WP
3	Carbendazim(12%) + Mancozeb(63%)	Methyl 1-2-benzimidazol carbamate + manganese ethylenebis dithiocarbamate	SAAF 75% WP
4	Propineb	Zinc propylene bisdithiocarbamate	Antracol 75 % WP

* International Union of Pure and Applied Chemistry

3.4.1.2 *In vitro* evaluation of commercially available 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 of the commercially available botanicals. The following botanicals were evaluated at 0.25, 0.5, 0.75 and 1.0 per cent concentration by following poison food technique as explained earlier.

Sl. No.	Common name / Trade name	Content
1	Neem gold	Azadirachtin 0.03%EC
2	Neem oil	Azadirachtin
3	Nimbidicine	Azadirachtin 0.03% EC
4	Sainik	Organic systemic fungicide
5	Soldier	<i>Aegle marbelos</i> (20%), <i>Ricinus communis</i> (20%), <i>Hygrophila spinosa</i> (20%), <i>Laminaria spp.</i> (20%) and <i>Lantana camera</i> (20%)
6	Wanis	Organic product (20%EC W/W)

3.4.1.3 *In vitro* evaluation of Indigenous technology knowledge (ITK^S)

Various ITK^S such as cow urine, cow milk, butter milk, panchagavya and vermiwash were evaluated *in vitro* condition by spore germination technique against *C. lunata* at 5, 10, 20 and 30% concentrations.

Panchagavya was taken from Organic Farming Institute, University of Agricultural Sciences, Raichur and vermiwash from vermiculturing unit, Regional Agricultural Research Station, Vijayapur.

The conidial suspension was prepared separately in sterile water to obtain 4×10^8 spores per ml. Then a drop of a spore (4×10^8) suspension was mixed with one drop of ITK^S solution in a cavity slide to achieve the required concentration. In each treatment six replications were maintained. Slides were incubated at room temperature ($28^\circ\text{C} \pm 1^\circ\text{C}$). The observation on spore germination was recorded at 6 hr after incubation (Salim and

Mahindpala, 1981) recorded at 6 hr after incubation under microscope at 40 X magnification. A control treatment was maintained with sterile water. Per cent spore germination was calculated by following formula.

$$\text{Per cent spore germination (PG)} = \frac{A}{B} \times 100$$

Where, A = No. of spore germinated

B = No. of spore observed

The Percent inhibition was calculated by the following formula given by Vincent (1947).

$$I = \frac{C - T}{C} \times 100$$

Where, I= Per cent inhibition

C = Spore germination percentage in control

T= Spore germination percentage in treatment

3.4.2 Evaluation of spray schedule

Field experiment was laid out in a randomized block design with three replications at Agricultural Research Station (ARS), Arabhavi, University of Agricultural Sciences, Dharwad, during *kharif* 2014. The economically viable and effective fungicide, botanical and ITK under *in vitro* evaluation were tested under field condition using the *Curvularia* leaf spot susceptible maize genotype, CP 818. The integration of fungicide, botanical and ITK were evaluated with the spraying schedule given below.

Treatments	Spray schedule	
	1 st Spray	2 nd Spray
T1	PBP	PBP
T2	ITK	ITK
T3	F1	F1
T4	F2	F2
T5	F1	PBP
T6	F2	PBP
T7	F1	ITK
T8	F2	ITK
T9	Unsprayed control	

PBP: Plant based product, ITK: Indigenous Technology Knowledge and F: Fungicide

Recommended package of practices was followed to raise the crop. The inoculum of *C. lunata* was sprayed uniformly on all the treatments 30 days after sowing to create high disease pressure. Two sprays were given in each treatment at 15 days interval starting from the onset of disease. Observations on disease severity were taken at physiological maturity by following 0 to 9 scale of Mayee and Datar (1986). Grain yield per plot and 100 grain weight were noted down after the harvest of the crop. Harvested grains from individual treatments were subjected for starch and oil estimation.

3.5 Screening of maize genotypes to *Curvularia* leaf spot

A total of 55 genotypes of maize as listed below, were screened under field condition at ARS, Arabhavi. Each genotype was sown in a single row of 3 mt length with a spacing of 60 cm X 20 cm. The inoculum of *C. lunata* was sprayed 20 days after sowing to create high disease pressure. The disease severity was recorded using 0-9 scale by (Mayee and Datar, 1986) randomly selecting five plants in each genotype. Based on their reaction genotypes were categorized into immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible.

Sl. No	Germplasm	Pedigree	Origin	Sl. No	Germplasm	Pedigree	Origin
1	ARYP 81	YP ⊗ 6 # 81	AICMIP, Arabhavi	29.	ARYP 2	YP ⊗ 6 # 2	AICMIP, Arabhavi
2	ARYP 83	YP ⊗ 6 # 83	AICMIP, Arabhavi	30.	KDMI 6		
3	ARYP 82	YP ⊗ 6 # 82	AICMIP, Arabhavi	31.	NAH 137		
4	ARYP 33	YP ⊗ 6 # 33	AICMIP, Arabhavi	32.	African Tall		
5	ARYP 53	YP ⊗ 6 # 53	AICMIP, Arabhavi	33.	MAH 974		
6	ARYP 36	YP ⊗ 6 # 36	AICMIP, Arabhavi	34.	MAH 957		
7	ARYP 64	YP ⊗ 6 # 64	AICMIP, Arabhavi	35.	NAH 1137		
8	ARYP 47	YP ⊗ 6 # 47	AICMIP, Arabhavi	36.	NAH 2049		
9	ARYP 63	YP ⊗ 6 # 63	AICMIP, Arabhavi	37.	Thaipop		
10	ARYP 60	YP ⊗ 6 # 60	AICMIP, Arabhavi	38.	SKV 50		
11	ARYP 74	YP ⊗ 6 # 74	AICMIP, Arabhavi	39.	Madhuri		
12	ARYP 46	YP ⊗ 6 # 46	AICMIP, Arabhavi	40.	NAC 6002		
13	ARYP 24	YP ⊗ 6 # 24	AICMIP, Arabhavi	41.	NAC 6004		
14	ARYP 6	YP ⊗ 6 # 6	AICMIP, Arabhavi	42.	GPMH 1111		
15	ARYP 43	YP ⊗ 6 # 43	AICMIP, Arabhavi	43.	GPMH 1101		
16	ARYP 28	YP ⊗ 6 # 28	AICMIP, Arabhavi	44.	GH 1043		
17	ARYP 30	YP ⊗ 6 # 30	AICMIP, Arabhavi	45.	DMH 100-3		
18	ARYP 68	YP ⊗ 6 # 68	AICMIP, Arabhavi	46.	BGMH 2		
19	ARYP 53	YP ⊗ 6 # 53	AICMIP, Arabhavi	47.	BGMH 1		
20	ARYP 23	YP ⊗ 6 # 23	AICMIP, Arabhavi	48.	GH 110204		
21	ARYP 76	YP ⊗ 6 # 76	AICMIP, Arabhavi	49.	GH 110145		
22	ARYP 39	YP ⊗ 6 # 39	AICMIP, Arabhavi	50.	CM 501		
23	ARYP 78	YP ⊗ 6 # 78	AICMIP, Arabhavi	51.	CI 4		CIMMYT, Mexico
24	ARYP 47	YP ⊗ 6 # 47	AICMIP, Arabhavi	52.	CI 5		
25	ARYP 25	YP ⊗ 6 # 25	AICMIP, Arabhavi	53.	KDMI 10		
26	ARYP 79	YP ⊗ 6 # 79	AICMIP, Arabhavi	54.	CM 111		DMR, Delhi
27	ARYP 14	YP ⊗ 6 # 14	AICMIP, Arabhavi	55.	Pop corn		
28	ARYP 61	YP ⊗ 6 # 61	AICMIP, Arabhavi				

Where, YP = Yellow Pool

4. EXPERIMENTAL RESULTS

The results of the experiment conducted on various aspects of maize Curvularia leaf spot (CLS) caused by *Curvularia lunata* with reference to survey, loss assessment aspects of the disease, *in vitro* evaluation of fungicides, commercially available botanicals and indigenous technology knowledge against pathogen, integrated management of the disease, screening of genotypes for resistance are presented below.

4.1 Survey

Roving survey was conducted during October –November 2014 in different taluks of Belagavi, Bagalkot and Vijayapur to know the severity of Curvularia leaf spot of maize in farmers fields. The results are presented in Table 1, Fig.1 and Plate 2.

Overall the disease severity was low in all the three districts surveyed and it was ranged between 2.44 to 9.02 per cent. Maximum disease severity of 9.02 per cent was recorded in Belagavi district followed by Bagalkot (5.31%) and Vijayapur (2.44%). Among the taluks Gokak had the maximum disease severity (9.83%) followed by Saundatti (8.97%), Jamakhandi (8.75%) and Raibhag (8.27%) and it was least in Indi (1.80%).

In Vijayapur district maximum disease severity of 3.36 per cent recorded in Vijayapur taluk followed by Basavan Bagewadi (2.41%), Sindagi (2.21%) and Indi (1.80%) taluks. Least disease severity of 1.20 per cent was recorded in Thamba village of Indi taluk. Jamakhandi taluk recorded maximum disease severity of 1.88 per cent was recorded in Bagalkot taluk of Bagalkot district. In Belagavi district maximum disease severity of 9.83 per cent was recorded in Gokak taluk followed by Saundatti (8.97%) and Raibhag taluk (8.27%).

Among the villages, Arabhavi of Gokak taluk recorded highest disease severity of 10.75 per cent followed Kalloli (9.81%) and Mudalgi (8.95%) villages of the same taluk.

In general disease severity was more in crop grown under irrigated conditions as compare to rainfed.

Table 1. Severity of maize Curvularia leaf spot in Belagavi, Bagalkot and Vijayapur districts of Karnataka during *kharif* 2014

District	Taluk	Village	Stage of the crop	Crop grown condition	Percent disease index
Vijayapur	Vijayapur	Aheri	Cob development	Rainfed	4.88
		Ankalagi	Cob development	Rainfed	1.80
		Chikkanura	Cob development	Rainfed	3.40
		Mean			3.36
	Indi	Atharga	Cob development	Rainfed	2.40
		Jambagi	Cob development	Rainfed	1.80
		Thamba	Cob development	Rainfed	1.20
		Mean			1.80
	Sindagi	Khadalewada	Cob development	Rainfed	0.96
		Neevalkeda	Cob development	Rainfed	2.27
		Devarhipparagi	Cob development	Rainfed	3.44
		Mean			2.21
	Basavana Bagewadi	Basavana Bagewadi	Cob development	Rainfed	2.33
		Ingaleshwar	Cob development	Rainfed	2.77
Muttagi		Cob development	Rainfed	2.14	
	Mean			2.41	
	District average				2.44
Bagalkot	Bagalkot	Rampur	Cob development	Rainfed	1.90
		Bevura	Cob development	Rainfed	2.08
		Thimmappur	Cob development	Rainfed	1.68
		Mean			1.88
	Jamakhandi	Hunnur	Cob development	Irrigated	7.91
		Kadapatti	Cob development	Irrigated	8.68
		Jamakhandi	Cob development	Irrigated	9.66
	Mean			8.75	
	District average				5.31
Belagavi	Saundatti	Saundatti	Cob development	Irrigated	8.06
		Munnoli	Cob development	Irrigated	8.82
		Yaragatti	Cob development	Irrigated	10.03
		Mean			8.97
	Gokak	Arabhavi	Cob development	Irrigated	10.75
		Kalloli	Cob development	Irrigated	9.81
		Mudalagi	Cob development	Irrigated	8.95
		Mean			9.83
	Raibhag	Kankanwadi	Cob development	Irrigated	8.63
		Mugalkhod	Cob development	Irrigated	8.39
Harugeri		Cob development	Irrigated	7.80	
	Mean			8.27	
	District average				9.02

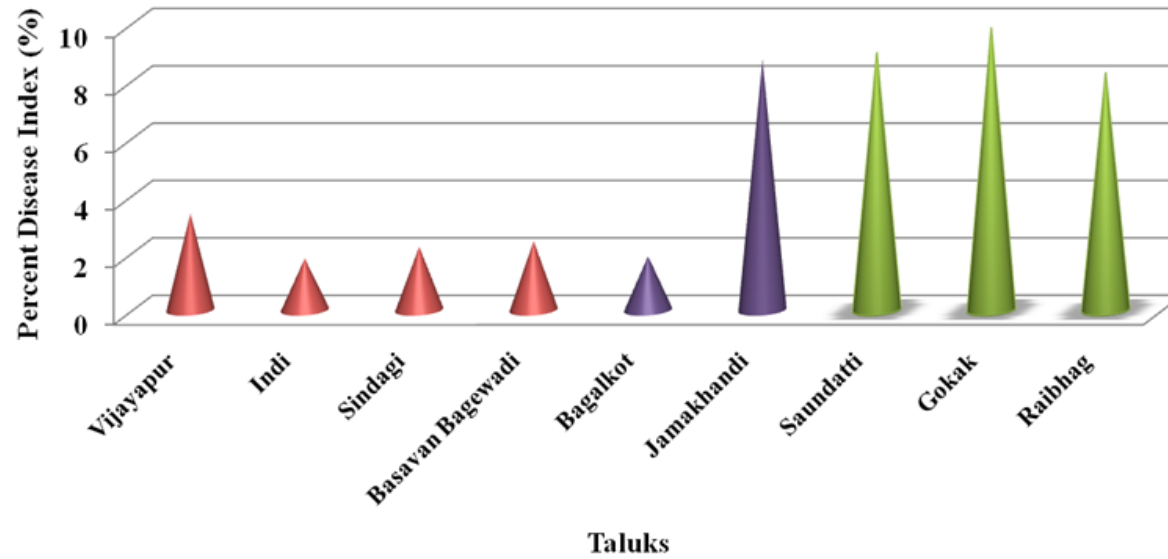


Fig.1. Severity of maize Curvularia leaf spot in Belagavi, Bagalkot and Vijayapur districts of Karnataka during *kharif* 2014



Aheri village of Vijayapur taluk



Kadapatti village of Jamakhandi taluk



Arabhavi village of Gokak taluk



Plate 2: Severity of Curvularia leaf spot in farmers field during *kharif*

2014

4.2 Isolation and proving the pathogenicity

Isolation of the pathogen was made from maize leaves showing typical symptoms of the disease. Leaves with such symptoms were collected for the isolation purpose (Plate 3a). Standard tissue isolation method was followed after surface disinfection as described in “Material and Methods”. The pure culture of the fungus was obtained after eight days of incubation which showed whitish growth at initial stage turning later to dark black colour (Plate 3b). Such pure culture obtained was again sub cultured in potato dextrose agar (PDA) slants and kept in the refrigerator at 5°C for further studies.

4.2.1 Pathogenicity test

For proving pathogenicity on host, the pathogen was artificially inoculated on the leaves of maize plants as described in “Material and Methods” (Plate 3c). After ten days of inoculation, the leaves exhibited symptoms of infection. The leaf on which exhibiting symptoms as small chlorotic spots which gradually expand into round or oval shaped lesion surrounded by a wide translucent straw yellow halo, lesions are about 0.5 cm per spot when fully developed. Further, they developed concentric rings and present a target board appearance which was better defined on the upper surface. The symptoms were photographed and are presented in Plate 3d. The pathogen was re-isolated from such leaves and the morphological character of the re-isolated organism was compared with the original culture of the pathogen which was similar in all respects. Hence, the causal agent of the disease was confirmed as *C. lunata*.

4.3 Loss assessment in maize genotypes due to *Curvularia* leaf spot

4.3.1 Per cent disease index (PDI)

The differences in the per cent disease index as influenced by different genotypes were found significant. The differences in (Table. 2) the per cent disease index in protected block was found significantly lower (4.68 %) compared to unprotected block (53.54 %).

Among different genotypes, irrespective of the fungicidal spray significantly higher per cent disease index was recorded in the genotype CP 818 (38.27 %) compared to other genotypes. Next genotype which was recorded higher per cent disease index was Arjun



Plate 3a. Infected maize leaf



Plate 3b. Isolation of

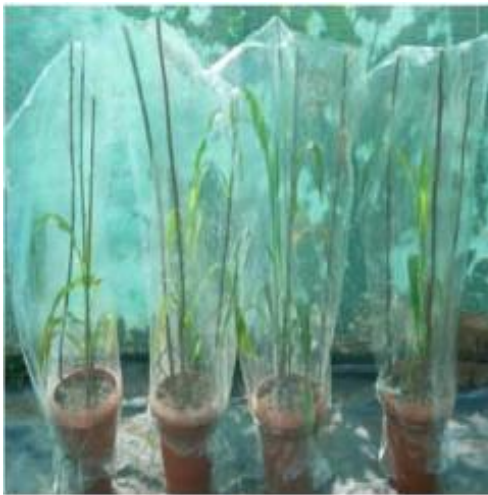


Plate 3c. Pathogen artificially inoculated on
20 days old maize plants



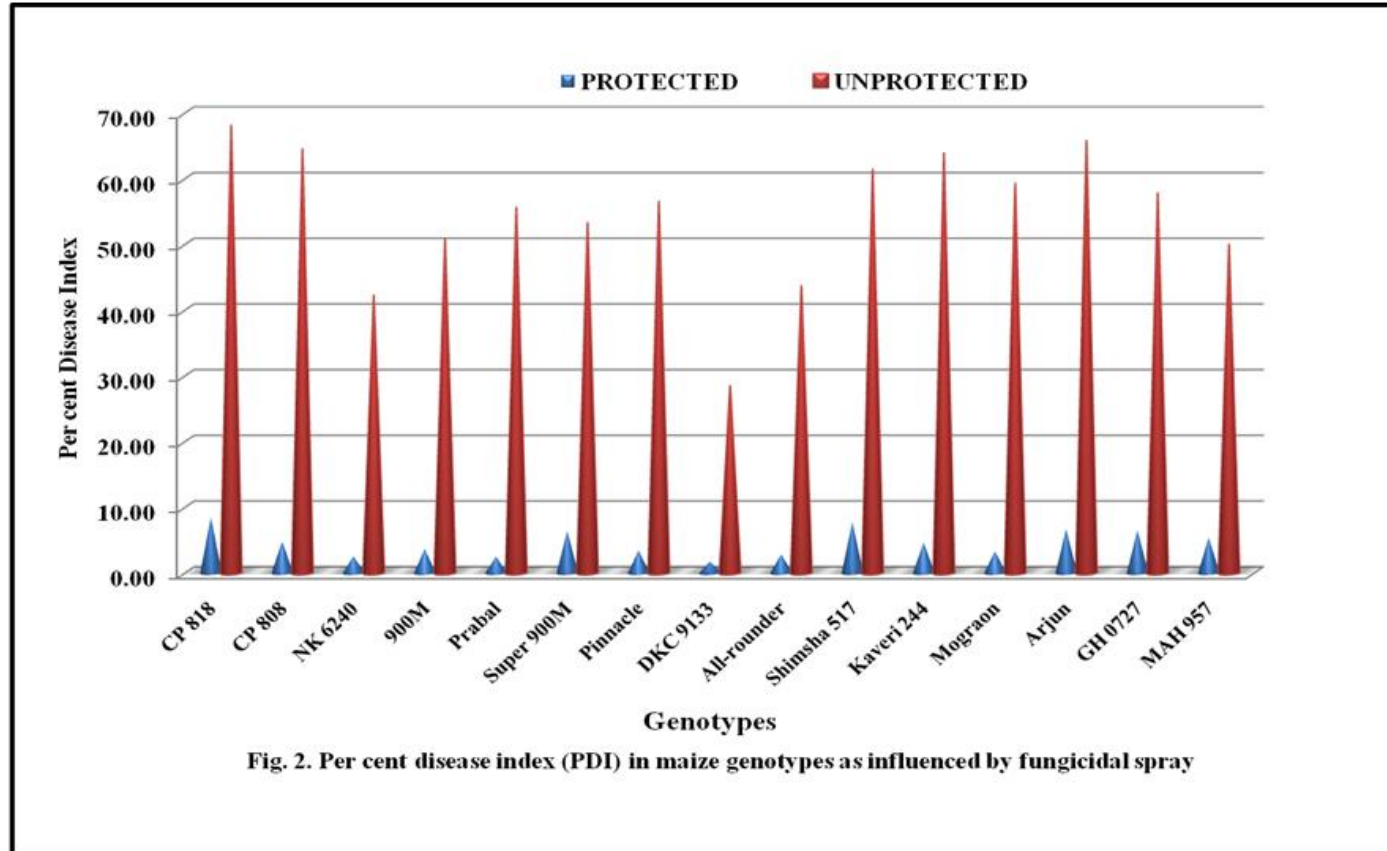
Plate 3d. Symptoms produced on
inoculated plant

Plate 3: Proving pathogenicity of *C.lunata* on maize

Table 2. Per cent disease index (PDI) in maize genotypes as influenced by fungicidal spray

Genotype	Protected	Un protected	Mean	Percent decrease over unprotected
CP 818	8.48 (16.93)*	68.06 (55.58)	38.27 (37.22)	87.54
CP 808	4.80 (12.65)	64.48 (53.42)	34.64 (36.05)	92.56
NK 6240	2.50 (09.09)	42.28 (40.56)	22.39 (28.24)	94.08
900M Gold	3.59 (10.92)	50.90 (45.52)	27.25 (31.46)	92.95
Prabal	2.46 (09.02)	55.61 (48.22)	29.03 (32.60)	95.98
Super 900M	6.36 (14.60)	35.05 (36.30)	20.70 (27.06)	81.85
Pinnacle	3.41 (10.63)	56.48 (48.72)	29.94 (33.17)	93.96
DKC 9133	1.70 (07.48)	28.47 (32.24)	15.08 (22.85)	94.02
All-rounder	2.82 (09.66)	43.68 (41.37)	23.25 (28.82)	93.54
Shimsha 517	7.72 (16.13)	61.39 (51.58)	34.55 (36.00)	87.42
Kaveri 244	4.61 (12.40)	63.89 (53.06)	34.25 (35.82)	92.78
Mograon	3.26 (10.39)	59.28 (50.35)	31.27 (34.00)	94.50
Arjun	6.67 (14.97)	65.74 (54.17)	36.20 (36.99)	89.85
GH 0727	6.50 (14.77)	57.78 (49.47)	32.14 (34.53)	88.75
MAH 957	5.36 (13.39)	49.99 (44.99)	27.68 (31.74)	89.28
Mean	4.68(12.49)	53.54(47.04)		
For comparing mean	S.Em±	C.D. at 5%		
Fungicidal spray(F)	2.29	6.83		
Genotype(G)	3.05	8.84		
Interaction (F×G)	4.31	12.50		
Interaction at the same or different level	4.25	12.34		

* Arc sine transformed values



(36.20%) followed by CP 808 (34.64%), Shimsha 517 (34.55%), and Kaveri 244 (34.25%) and were on par with each other and least per cent disease index was recorded in the genotype DKC 9133 with severity of 15.08 per cent.

The differences in the PDI within the genotype, CP 818 recorded higher per cent disease index (8.48 %) and it was on par with Shimsha 517(7.72%), GH 0727 (6.50%), Arjun (6.67%), and by GH 0727 in protected block. Similarly the genotypes CP 818 was recorded significantly higher PDI (68.06 %) compared to other genotypes in unprotected block (Fig. 2, Plate 4a and Plate 4b).

Among all genotypes, CP 818 was recorded significantly higher PDI (8.48%) in protected block as well as in unprotected block (68.04 %).

Among the genotypes, highest decrease in per cent disease severity over unprotected block was recorded in the genotype Prabal (95.98 %) followed by Mograon (94.50 %). Lowest decrease in per cent disease index was recorded in Super900M (81.85%).

4.3.2 Grain yield (q ha^{-1})

The differences in the grain yield as influenced by different genotypes were found significant. The differences in the grain yield in protected block were found significantly higher (74.14 q) compared to unprotected block (52.96 q). (Table.3)

Among the genotypes, irrespective of the fungicidal spray significantly higher grain yield was recorded in the genotype Mograon (80.32q) compare other genotypes. Next followed by Pinnacle (80.28 q) and were on par with each other. Next genotype which was recorded higher grain yield was Prabal (66.62 q) and significantly least grain yield was recorded in the genotype Arjun (34.07 q) and followed by GH 0727 (49.54 q).

The differences in the grain yield within the genotype in protected block, significantly higher grain yield was recorded 90.46 q in the genotypes of Mograon and Pinnacle and on par with NK 6240 (88.33 q). Significantly least grain yield was recorded in the genotype Arjun (42.59 q) followed by Shimsha 517 was recorded 57.78 q .

Similarly within the genotype in unprotected block, significantly higher grain yield was recorded in the genotypes of Mograon (70.19 q) and Pinnacle (70.09 q) on par with



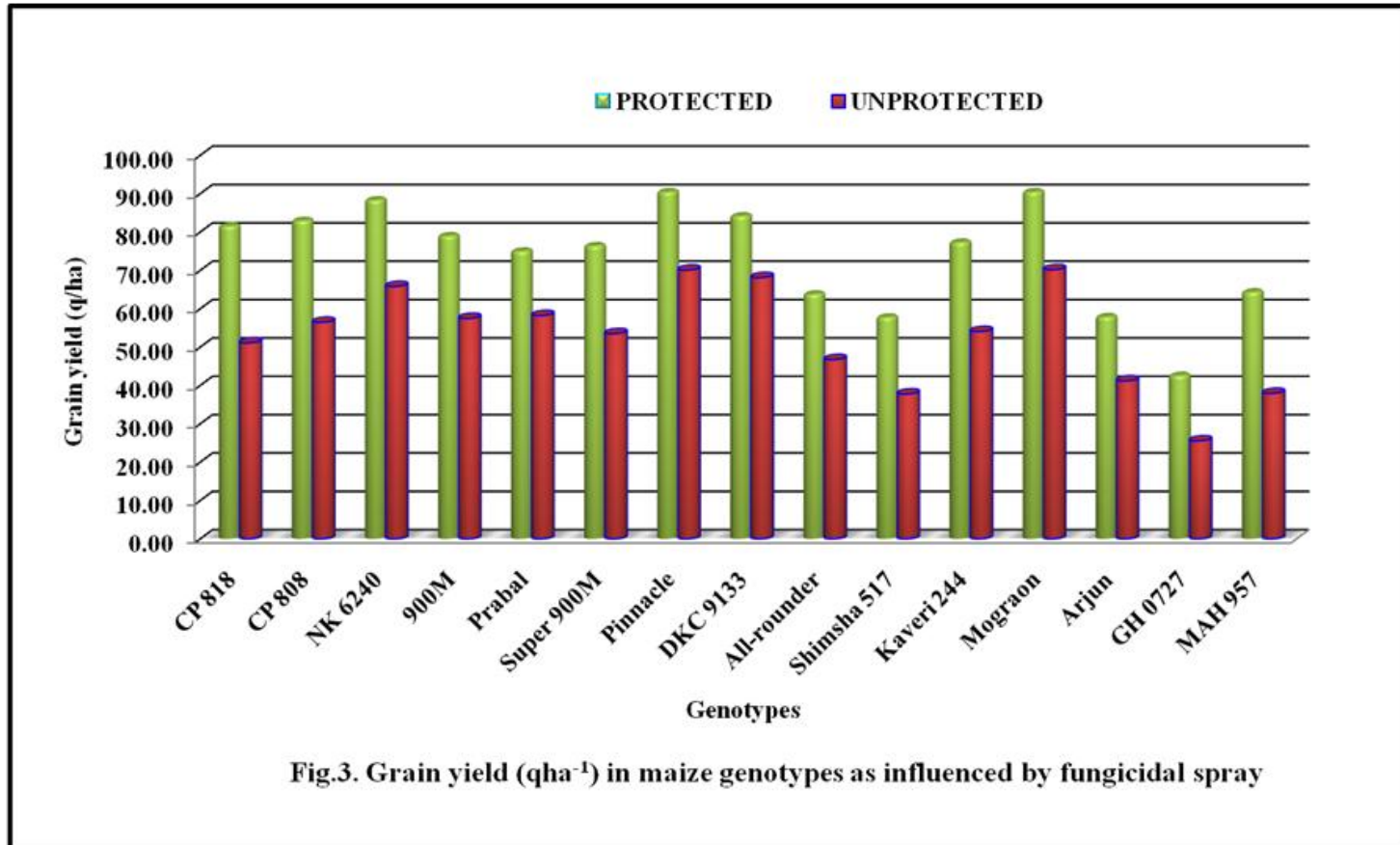
Plate 4a: Curvularia leaf spot severity in maize genotypes as influenced by fungicidal spray



Plate 4b: Curvularia leaf spot severity in maize genotypes as influenced by fungicidal spray

Table 3. Grain yield (qha⁻¹) in maize genotypes as influenced by fungicidal spray

Genotype	Protected	Unprotected	Mean	Percent loss in grain yield
CP 818	81.57	51.11	66.34	37.34
CP 808	82.96	56.48	69.72	31.92
NK 6240	88.33	65.83	77.08	25.47
900M Gold	78.98	57.50	68.24	27.20
Prabal	75.00	58.24	66.62	22.35
Super 900M	76.39	53.52	64.95	29.94
Pinnacle	90.46	70.09	80.28	22.52
DKC 9133	84.17	68.15	76.16	19.03
All-rounder	63.80	46.76	55.28	26.71
Shimsha 517	57.78	37.78	47.78	34.61
Kaveri 244	77.31	54.07	65.69	30.06
Mograon	90.46	70.19	80.32	22.41
Arjun	42.59	25.56	34.07	39.99
GH 0727	57.87	41.20	49.54	28.81
MAH 957	64.35	37.96	51.16	41.00
Mean	74.14	52.96		
For comparing mean	S.Em±	C.D. at 5%		
Fungicidal spray(F)	2.1	6.5		
Genotype(G)	2.9	8.5		
Interaction (F×G)	4.1	12.1		
Interaction at the same or different level	4.5	13.2		



DKC9133 was recorded 68.15 q. Significantly lowest grain yield of 25.56 q/ha was recorded in the genotype Arjun followed by MAH 957 was recorded 37.96 q (Fig. 3).

Among all genotypes, Mograon was recorded significantly higher grain yield both in protected block as well as in unprotected block 90.46q and 70.19q respectively.

Among the genotypes, irrespective of the spray highest per cent loss in grain yield was recorded in the genotype MAH 957 (41.00 %) followed by Arjun (39.99%). Lowest per cent loss in grain yield was recorded in DKC 9133 (19.03 %).

4.3.3 100 grain weight (g)

The differences in the 100 grain weight as influenced by different genotypes were found significant. The differences in (Table.4) the 100 grain weight in protected block was found significantly higher (38.17 g) compared to unprotected block (35.73 g).

Irrespective of the fungicidal spray the genotypes NK 6240 recorded significantly highest 100 grain weight of 40.75 g. Shimsha 517 and DKC 9133 were the next genotypes recorded higher 100 grain weight of 39.50 g followed by CP 818 (38.50 g), Prabal (39.25 g) and CP 808 (38.75 g) and were on par with each other. Genotype Arjun recorded least 100 grain weight of 33.00 g and it was on par with GH 0727 (33.50 g) and MAH 957 (34.00 g).

In protected block the genotype NK 6240 and Shimsha 517 recorded significantly highest 100 grain weight 41.50 g compare to other genotypes. The least 100 grain weight 34.50 g was recorded in the genotype Arjun and it was on par with GH 0727 and MAH 957 (35.00 g) (Fig.4).

Similarly within the genotype in unprotected block, significantly higher 100 grain weight was recorded in the genotype NK 6240 (40.00 g) compared to other genotypes. Prabal and DKC9133 (38.50 g) were the next genotypes which have recorded higher 100 grain weight compare to other genotypes. Least 100 grain weight was recorded in the Arjun (31.50 g) and it was on par with GH 0727 (32.00 g) and MAH 957 (33.00g).

Table 4. 100 grain weight (g) in maize genotypes as influenced by fungicidal spray

Genotype	Protected	Unprotected	Mean	Percent loss in 100 grain weight
CP 818	40.00	37.00	38.50	7.50
CP 808	39.50	38.00	38.75	3.80
NK 6240	41.50	40.00	40.75	3.61
900M Gold	37.50	35.00	36.25	6.67
Prabal	40.00	38.50	39.25	3.75
Super 900M	38.50	36.00	37.25	6.49
Pinnacle	37.50	35.00	36.25	6.67
DKC 9133	40.50	38.50	39.50	4.94
All-rounder	37.50	34.50	36.00	8.00
Shimsha 517	41.50	37.50	39.50	9.64
Kaveri 244	37.50	35.00	36.25	6.67
Mograon	36.50	34.50	35.50	5.48
Arjun	34.50	31.50	33.00	8.70
GH 0727	35.00	32.00	33.50	8.57
MAH 957	35.00	33.00	34.00	5.71
Mean	38.17	35.73		
For comparing mean	S.Em \pm	C.D. at 5%		
Fungicidal spray(F)	0.96	2.96		
Genotype(G)	0.54	1.56		
Interaction (F \times G)	0.76	2.21		
Interaction at the same or different level	0.75	2.19		

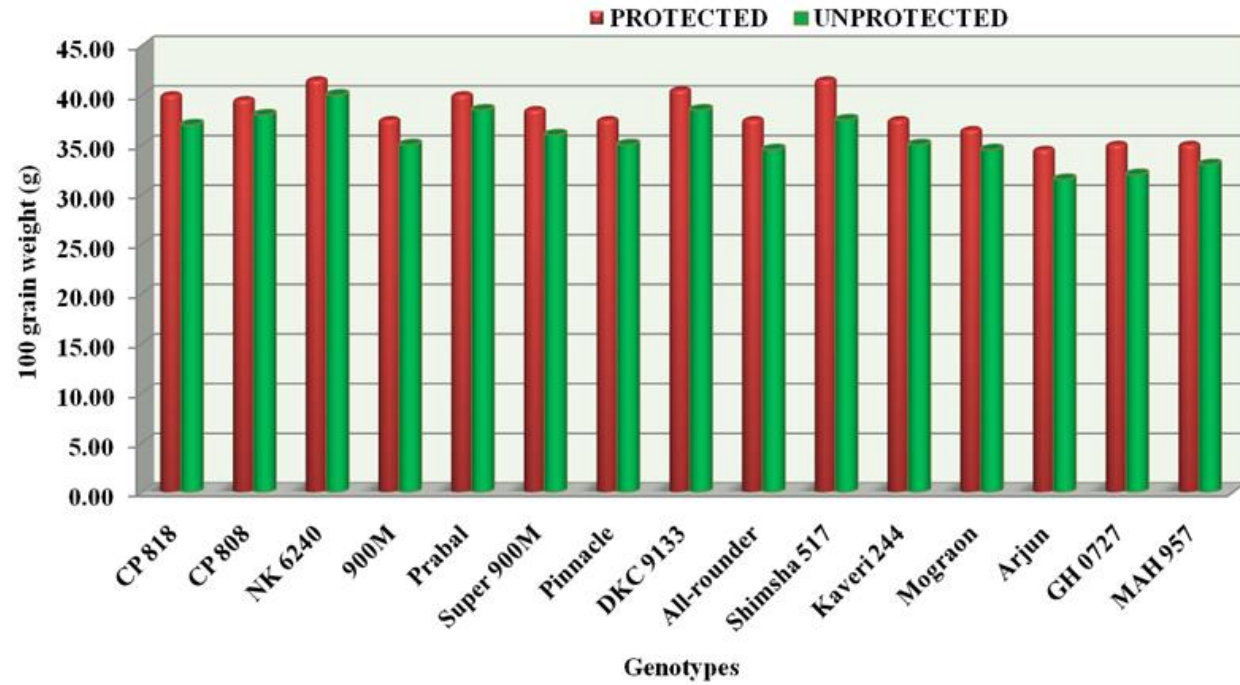


Fig. 4. 100 grain weight (g) in maize genotypes as influenced by fungicidal spray

Among all genotypes, NK 6240 has recorded significantly higher 100 grain weight (41.50g) in protected block as well as in unprotected block (40.00g).

Among the genotypes, irrespective of the spray highest per cent loss in 100 grain weight was recorded in the genotype Shimsha 517 (9.64%) followed by Arjun (8.70 %). Lowest per cent loss in 100 grain weight was recorded in NK 6240 (3.61%).

4.3.4. Stover yield (t ha^{-1})

The differences in the stover yield as influenced by different genotypes and fungicidal spray were found significant. The stover yield in protected block was found significantly higher (7.56 t) compared to unprotected block (6.85 t) (Table 5).

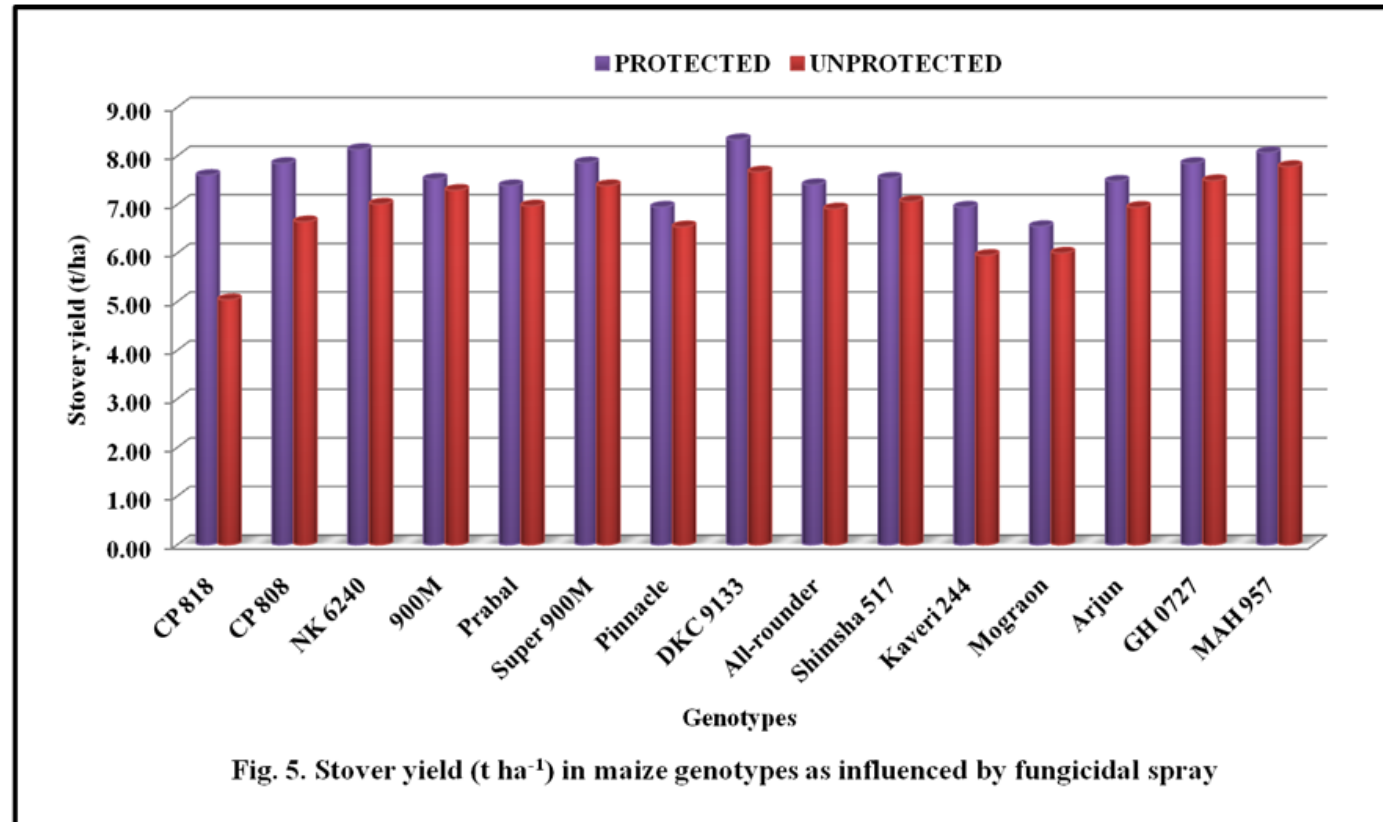
Irrespective of the fungicidal spray higher stover yield was recorded in the genotype DKC9133 (8.00 t) followed by MAH 957 (7.92 t) and GH 0727(7.67t) and were on par with each other. Super 900M was the next genotype which was recorded 7.62 t and it was on par with NK 6240 (7.57 t) and 900M Gold (7.41 t). Significantly least stover yield of 6.27 t was recorded in the genotype Mograon and it was on par with CP 818 (6.32 t).

In protected block, higher stover yield of 8.33 t was recorded in DKC 9133 (8.33 t) followed by NK 6240 (8.13 t), and MAH 957 (8.06 t) and were on par with each other. Next genotype has recorded stover yield was Super 900M (7.86 t) and it was on par with CP 808 and GH 0727 genotypes with stover yield 7.84 t and CP 818 (7.60 t).

Similarly within the genotype in unprotected block, the higher stover yield was recorded in the genotype MAH 957 (7.78 t) followed by DKC 9133 (7.67 t) and were on par with each other. Next genotype which has recorded higher stover yield was GH 0727 (7.49 t) and it was on par with Super 900M (7.39 t), and 900M Gold (7.29 t). Significantly least stover yield was recorded in the genotype CP 818 (5.04 t) compared to other genotypes (Fig.5).

Table 5. Stover yield (t ha⁻¹) in maize genotypes as influenced by fungicidal spray

Genotype	Protected	Unprotected	Mean	Percent loss in Stover yield
CP 818	7.60	5.04	6.32	33.68
CP 808	7.84	6.64	7.24	15.31
NK 6240	8.13	7.01	7.57	13.78
900M Gold	7.52	7.29	7.41	3.06
Prabal	7.39	6.97	7.18	5.68
Super 900M	7.86	7.39	7.62	5.98
Pinnacle	6.94	6.54	6.74	5.76
DKC 9133	8.33	7.67	8.00	7.92
All-rounder	7.41	6.91	7.16	6.75
Shimsha 517	7.54	7.06	7.30	6.37
Kaveri 244	6.94	5.95	6.45	14.27
Mograon	6.55	6.00	6.27	8.40
Arjun	7.48	6.94	7.21	7.22
GH 0727	7.84	7.49	7.67	4.46
MAH 957	8.06	7.78	7.92	3.47
Mean	7.56	6.85		
For comparing mean	S.Em±	C.D. at 5%		
Fungicidal spray(F)	0.027	0.083		
Genotype(G)	0.074	0.214		
Interaction (F×G)	0.104	0.303		
Interaction at the same or different level	0.104	0.302		



Among all genotypes, DKC 9133 has recorded significantly higher stover yield in protected block (8.33 t) as well as in unprotected block (7.67 t).

Among the genotypes, irrespective of the spray highest per cent loss in stover yield was recorded in the genotype CP 818 (33.68%) followed by CP 808 (15.31 %). Lowest percent loss in stover yield was recorded in 900M Gold (3.06 %).

4.3.5. Starch content (%)

The difference in the starch content as influenced by different genotypes and fungicidal spray were found non significant (Table.6). However within the protected block genotypes Super 900 M recorded numerically higher starch content (71.50%) followed by CP 818 (71.20%), NK 6240 and Shimsha 517 (71.00%). Lowest starch content of 69.30 per cent was recorded in Arjun.

Similarly in unprotected block maximum starch content was recorded in NK 6240 (71.00%) and minimum was in Arjun (69.10%). There is little difference in starch content between protected (70.67%) and unprotected block (70.28%).

4.3.6. Oil content (%)

The differences in the oil content, irrespectively. The genotypes in protected (4.73%) and unprotected (4.47%) block were found significantly (Table.7).

Irrespective of the fungicidal spray the genotype Prabal recorded highest oil content of 4.90 % followed by CP 818 and Super 900M (4.75 %), CP 818 and Kaveri 244(4.73%), Shimsha 517 (4.70 %), GH 0727 and Arjun (4.68 %), All rounder (4.60 %), Pinnacle (4.58 %), MAH 957 (4.55 %) and NK 6240 (4.48 %) and were on par with each other. Least oil content of 4.28 per cent recorded in DKC 9133 and it was on par with 900M Gold and Mograon (4.33 %).

Table 6. Per cent starch content in maize genotypes as influenced by fungicidal spray

Genotype	Protected	Unprotected	Mean	Percent loss in starch content
CP 818	71.20(57.54)*	70.90(57.35)	71.05(57.45)	0.42
CP 808	70.80(57.29)	70.40(57.04)	70.60(57.17)	0.56
NK 6240	71.00(57.42)	71.00(57.42)	71.00(57.42)	0.00
900M Gold	70.80(57.23)	70.70(57.29)	70.75(57.26)	0.14
Prabal	70.70(57.23)	70.70(57.23)	70.70(57.23)	0.00
Super 900M	71.50(57.73)	70.80(57.29)	71.15(57.51)	0.98
Pinnacle	71.00(57.42)	70.70(57.23)	70.85(57.32)	0.42
DKC 9133	70.80(57.29)	70.40(57.04)	70.60(57.17)	0.56
All-rounder	70.80(57.29)	70.50(57.10)	70.65(57.20)	0.42
Shimsha 517	71.00(57.42)	70.00(56.79)	70.50(57.10)	1.41
Kaveri 244	70.80(57.29)	70.10(56.85)	70.45(57.07)	0.99
Mograon	70.90(57.35)	70.00(56.79)	70.45(57.07)	1.27
Arjun	69.30(56.35)	69.10(56.23)	69.20(56.29)	0.29
GH 0727	69.70(56.60)	69.20(56.29)	69.45(56.45)	0.72
MAH 957	69.80(56.66)	69.60(56.54)	69.70(56.60)	0.29
Mean	70.67(57.21)	70.28(56.97)		
For comparing mean	S.Em±	C.D. at 1%		
Fungicidal spray(F)	0.61	NS		
Genotype(G)	1.92	NS		
Interaction (F×G)	2.71	NS		
Interaction at the same or different level	2.69	NS		

* Arc sine transformed values

Table 7. Per cent oil content in maize genotypes as influenced by fungicidal spray

Genotype	Protected	Unprotected	Mean	Percent loss in oil content
CP 818	4.85(12.72)*	4.65(12.45)	4.75(12.59)	4.12
CP 808	4.85 (12.72)	4.60(12.38)	4.73(12.55)	5.15
NK 6240	4.70 (12.52)	4.25(11.90)	4.48(12.21)	9.59
900M Gold	4.60 (12.38)	4.05(11.61)	4.33(12.00)	11.95
Prabal	4.95 (12.86)	4.85(12.75)	4.90(12.79)	2.02
Super 900M	4.90 (12.79)	4.60(12.38)	4.75(12.59)	6.12
Pinnacle	4.60 (12.38)	4.55(12.32)	4.58(12.35)	1.08
DKC 9133	4.45 (12.18)	4.10(11.68)	4.28(11.93)	7.84
All-rounder	4.70 (12.52)	4.50(12.25)	4.60(12.38)	4.24
Shimsha 517	4.80 (12.66)	4.60(12.38)	4.70(12.52)	4.16
Kaveri 244	4.75 (12.59)	4.70(12.52)	4.73(12.55)	1.05
Mograon	4.45 (12.18)	4.20(11.83)	4.33(12.00)	5.61
Arjun	4.80 (12.66)	4.55(12.32)	4.68(12.49)	5.20
GH 0727	4.85 (12.72)	4.50(12.25)	4.68(12.49)	7.21
MAH 957	4.75(12.59)	4.35(12.04)	4.55(12.32)	8.42
Mean	4.73(12.57)	4.47(12.21)		
For comparing mean	S.Em±	C.D. at 1%		
Fungicidal spray(F)	0.98	2.96		
Genotype(G)	0.14	0.56		
Interaction (F×G)	0.20	0.79		
Interaction at the same or different level	0.20	0.78		

* Arc sine transformed values

The interaction effect was also found significant. Among the genotypes, Prabal recorded higher oil content both in protected (4.95 %) and unprotected (4.65 %) blocks.

Among the genotypes, irrespective of the spray highest percent loss in oil content was recorded in the genotype 900M Gold (11.95%) followed by NK6240 (9.59 %). Lowest percent loss in oil content was recorded in Kaveri 244(1.05 %) followed by Pinnacle (1.08%).

4.4 Integrated management of *Curvularia* leaf spot

4.4.1 *In vitro* evaluation of fungicides, commercially available botanicals and indigenous technology knowledge against *C. lunata*

4.4.1.1 Fungicides

In vitro evaluation of fungicides was conducted with respect to inhibition of mycelial growth of *C. lunata* at different concentrations of fungicides as explained in “Material and Methods” and the results are presented(Table 8, Fig 6a and 6b).

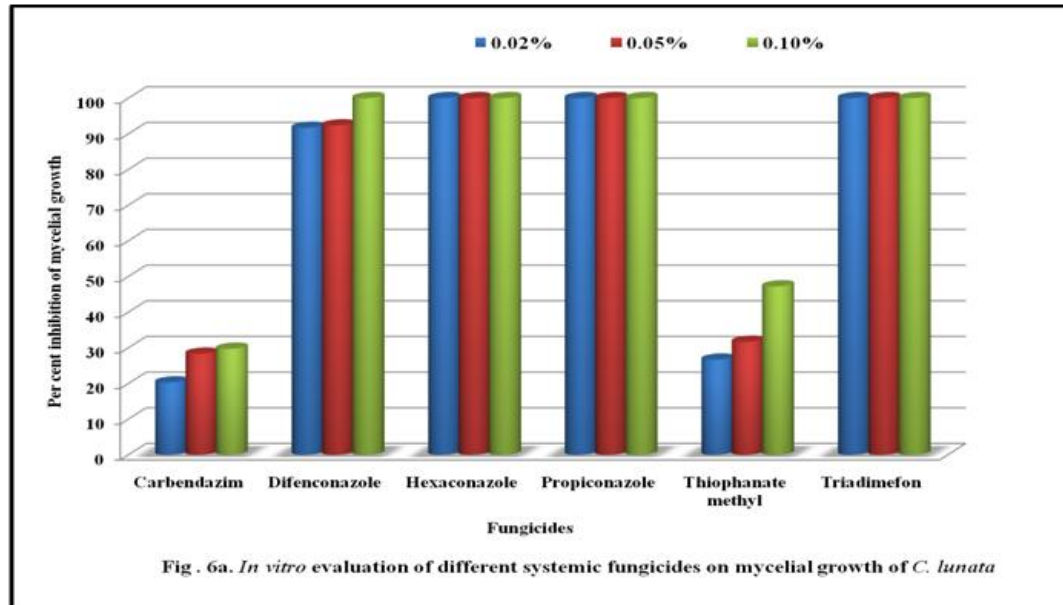
The efficacy of six systemic and four non systemic fungicides on inhibition of mycelial growth of *C. lunata* was carried out. Among systemic fungicides at 0.025 per cent concentration, the highest inhibition was observed in three chemicals viz.,hexaconazole, propiconazole and triadimefon (100.00%) followed by difenconazole (91.67%). Least inhibition of mycelial growth was observed in carbendazim (20.28 %) followed by thiophanate methyl (26.67 %). At 0.05 per cent concentration, highest inhibition was observed in three chemicals viz., hexaconazole, propiconazole and triadimefon (100.00%) followed by difenconazole (92.36%). Least inhibition of mycelial growth was observed in carbendazim (28.33 %) followed by thiophanate methyl (31.67%) At 0.1 per cent concentration, maximum inhibition was observed in four chemicals viz., hexaconazole, propiconazole, triadimefon and difenconazole (100.00%) and least inhibition of mycelial growth was observed in carbendazim (29.72%) followed by thiophanate methyl(47.21%). Irrespective of fungicide concentration, hexaconazole

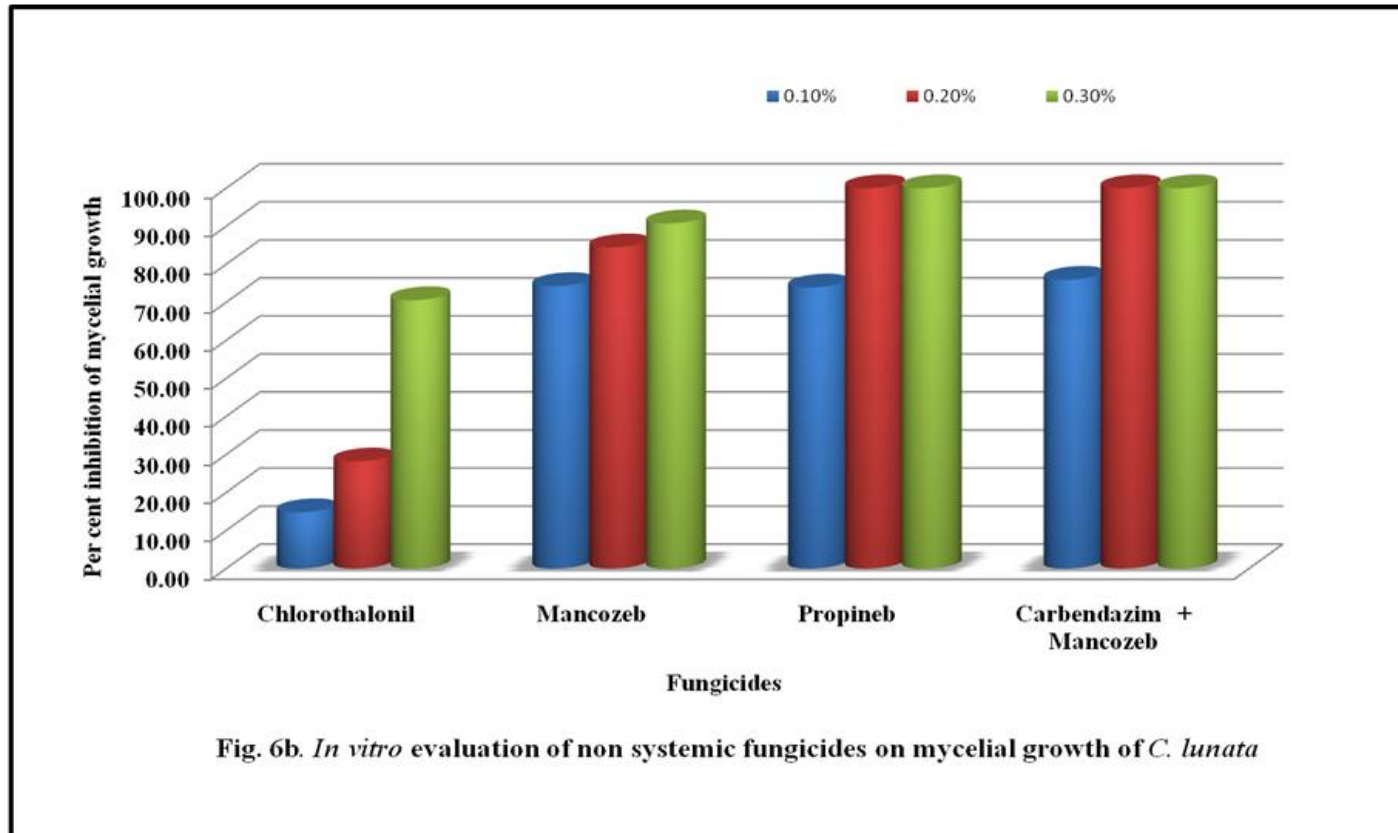
Table 8. *In vitro* evaluation of different systemic and non systemic fungicides on mycelial growth of *C. lunata*

Sl. No.	Systemic fungicides	Per cent inhibition of mycelial growth over control			
		0.025%	0.05%	0.1%	Mean
1	Carbendazim	20.28(26.75)*	28.33(32.16)	29.72(33.03)	26.11(30.73)
2	Difenconazole	91.67(73.33)	92.36(73.95)	100.00(90.00)	94.67(76.66)
3	Hexaconazole	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
4	Propiconazole	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
5	Thiophanate methyl	26.67(31.09)	31.67(34.25)	47.21(43.40)	35.18(36.38)
6	Triadimefon	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
Mean		56.43(48.69)	75.39(60.26)	79.48(63.06)	75.19(57.54)
		Fungicides (F)		Concentration (C)	FxC
S.Em±		1.25		0.88	2.17
C.D.at 1%		4.74		3.35	8.21

Sl. No.	Non systemic fungicides	Per cent inhibition of mycelial growth over control			
		0.1 %	0.2%	0.3%	Mean
1	Chlorothalonil	14.81(22.63)*	28.15(32.04)	70.56(57.14)	37.84(37.96)
2	Mancozeb	74.26(59.51)	84.44(66.77)	90.74(72.28)	83.15(65.76)
3	Propineb	73.89(59.27)	100.00(90.00)	100.00(90.00)	91.30(72.84)
4	Carbendazim 12% WP + Mancozeb 63% WP	75.93(60.62)	100.00(90.00)	100.00(90.00)	91.98(73.55)
Mean		59.72(47.48)	78.15(69.59)	90.33(71.88)	76.07(60.71)
		Fungicides (F)		Concentration (C)	FxC
S.Em±		0.25		0.22	0.44
C.D.at 1%		0.96		0.82	1.65

* Arc sine transformed values





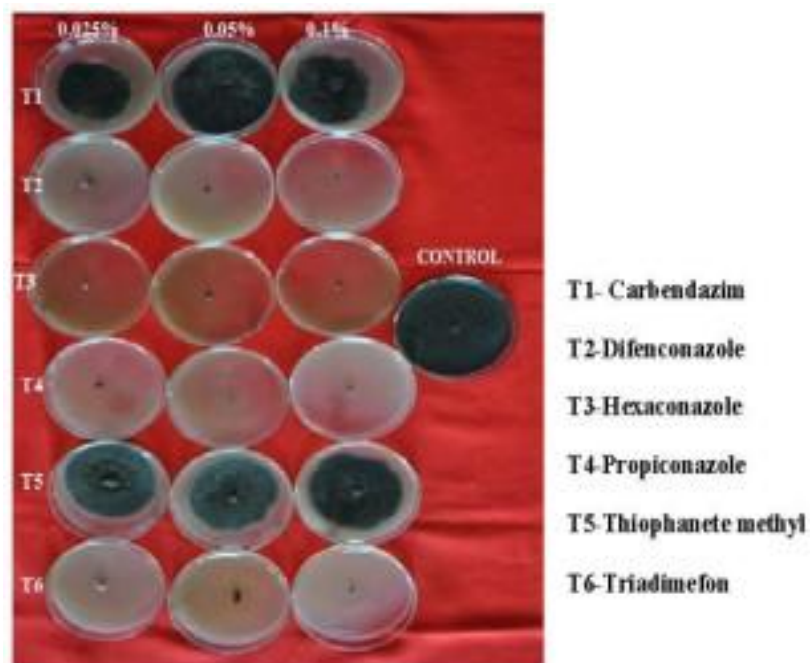


Plate 5a. *In vitro* evaluation of systemic fungicides

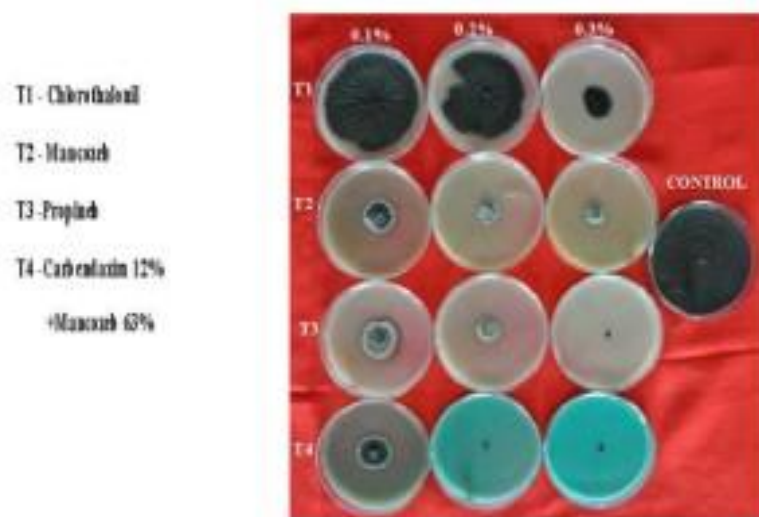


Plate 5b. *In vitro* evaluation of non systemic fungicides

Plate 5: *In vitro* evaluation of fungicides against *C. lunata*

propiconazole and triadimefon (100.00%) were found to be the best in inhibiting the radial growth and next best was difenconazole (94.67%) followed by thiophanate methyl (35.18 %) (Plate 5a).

Among non systemic fungicides at 0.1 per cent concentration, maximum inhibition was observed in carbendazim + mancozeb (75.93 %) which was on par with mancozeb (74.26 %) and propineb (73.89 %). Least inhibition of radial growth was observed in chlorothalonil (14.81 %). At 0.2 per cent concentration, maximum inhibition was observed in two fungicides *viz.*, carbendazim + mancozeb and propineb (100%) followed by mancozeb (84.44%). Least inhibition of radial growth was observed in chlorothalonil (28.15%). At 0.3 per cent concentration, highest inhibition observed in two fungicides *viz.*, carbendazim + mancozeb and propineb (100%) followed by mancozeb (90.74 %). Least inhibition of radial growth was observed in chlorothalonil (70.56 %). Irrespective of fungicide concentration, carbendazim + mancozeb (91.97 %) was found to be the best in inhibiting the radial growth and remain on par with propineb (91.29 %), followed by mancozeb (83.14%). Least inhibition was observed in chlorothalonil (37.84%) (Plate 5b).

As the concentration of fungicides increased, the inhibition of radial growth was also increased.

4.4.1.2 Commercially available botanicals

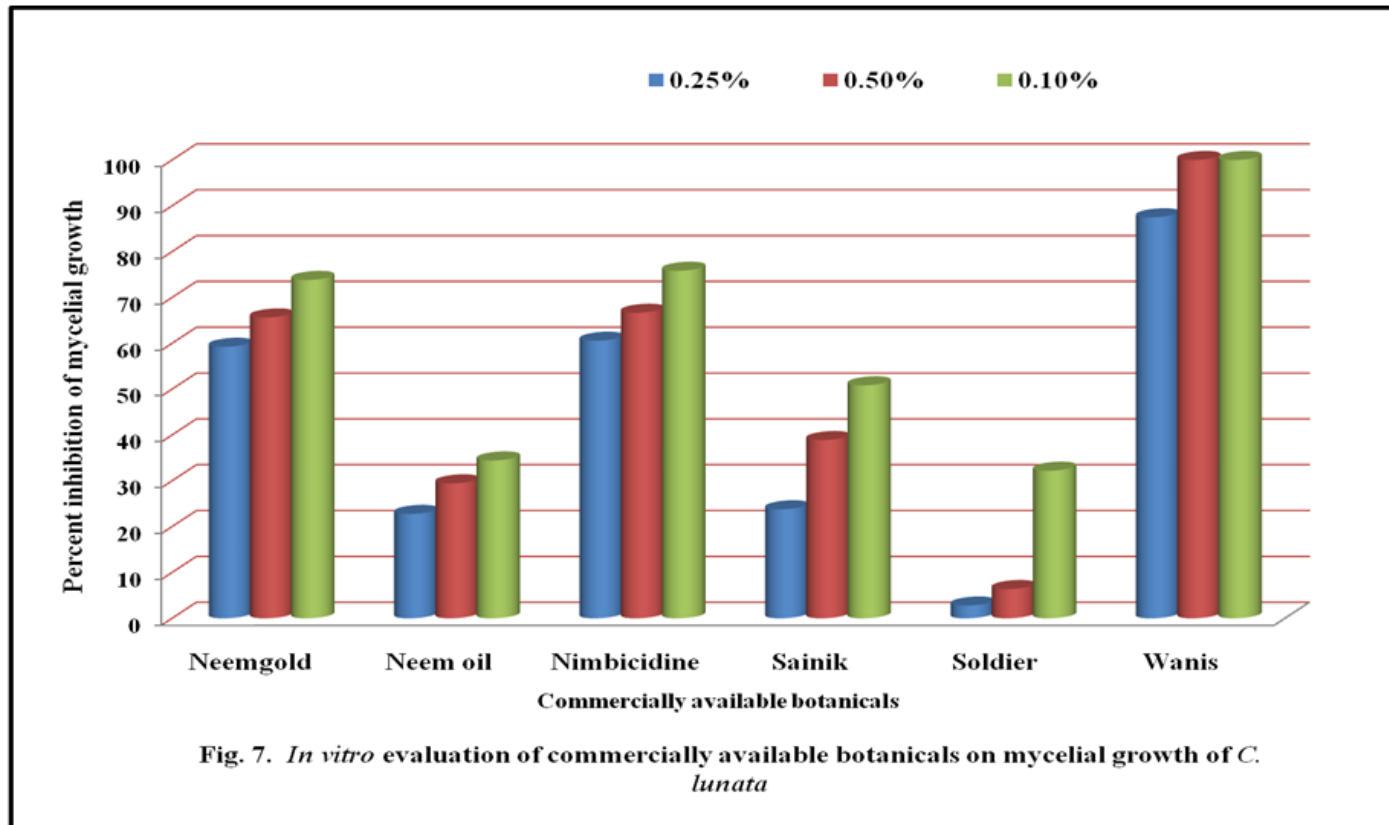
In vitro evaluation of commercially available botanicals was conducted with respect to inhibition of mycelial growth of *C. lunata* at different concentrations as explained in “Material and Methods” and the results are presented in Table 9 and Fig 7.

Six test botanicals reduced the inhibition of radial growth of *C. lunata* at 0.25 per cent, 0.50 per cent, 0.75 per cent and 1.00 per cent concentration. At 0.25 per cent per cent concentration, maximum inhibition was noticed in wanis (87.50 %) followed by nimbidicine (60.56%) and neemgold (59.25 %) and were on par with each other. Next best was sainik (23.78 %). Least inhibition was noticed in soldier (2.78 %) followed by neem oil (22.78%). At 0.5 per cent per cent concentration, highest inhibition was noticed in

Table 9. *In vitro* evaluation of commercially available botanicals on mycelial growth of *C. lunata*

Sl. No.	Botanicals	Percent inhibition of mycelial growth over control at different concentration (%)			
		0.25	0.5	0.1	Mean
1	Neemgold	59.25(50.33)*	65.64(54.74)	73.83(60.55)	66.24(54.48)
2	Neem oil	22.78(28.51)	29.44(32.86)	34.44(35.93)	28.88(32.51)
3	Nimbicidine	60.56(51.10)	66.67(54.74)	75.83(60.56)	67.69(55.35)
4	Sainik	23.78(28.41)	38.89(38.58)	50.83(45.48)	37.50(37.76)
5	Soldier	2.78(09.60)	6.39(14.64)	32.21(34.58)	13.79(21.80)
6	Wanis	87.50(69.30)	100.00(90.00)	100.00(90.00)	95.83(78.22)
Mean		42.61(40.75)	51.17(45.67)	61.19(51.47)	
		Botanical(B)		Concentration (C)	BxC
S.Em±		1.98		1.40	3.43
C.D.at 1%		7.48		5.28	NS

* Arc sine transformed values



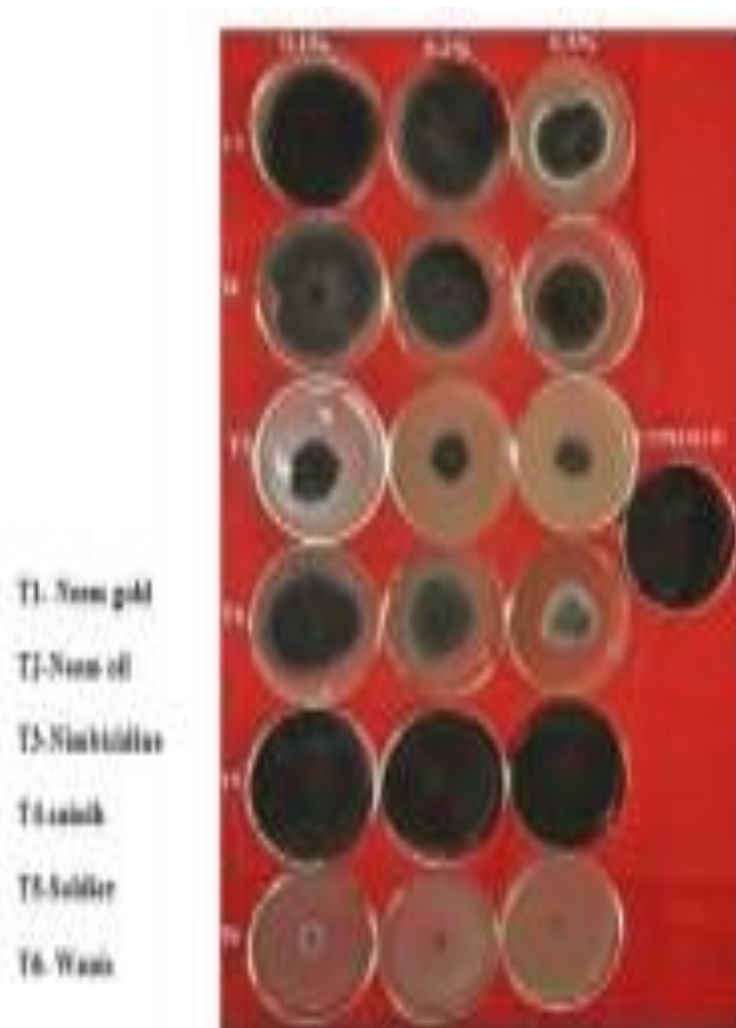


Plate 6: *In vitro* evaluation of commercially available botanicals against *C. lunata*

wanis (100%) followed by nimbicidine (66.67 %) and neemgold (65.64 %) which were on par with each other. Next best was sainik (28.89 %). Least inhibition was noticed in soldier (6.39 %) followed by neem oil (29.44%). At 1 % per cent concentration, highest inhibition was noticed in wanis (100%) followed by nimbicidine (75.83 %) and neemgold (73.83 %) and were on par with each other. Next best was sainik (50.83 %). Least inhibition was noticed in soldier (32.21 %) followed by neem oil (34.44%). Maximum inhibition of radial growth irrespective of the botanical concentration was noticed with wanis (95.83%) followed by nimbicidine (67.69 %) and neem gold (66.24 %) whereas least inhibition of mycelial growth was observed in soldier (13.34 %) followed by sainik (37.83 %) (Plate 6).

4.4.1.3 ITK^S

In the present experiment, five ITK^S were evaluated and results obtained are presented in Table 10 and Fig 8.

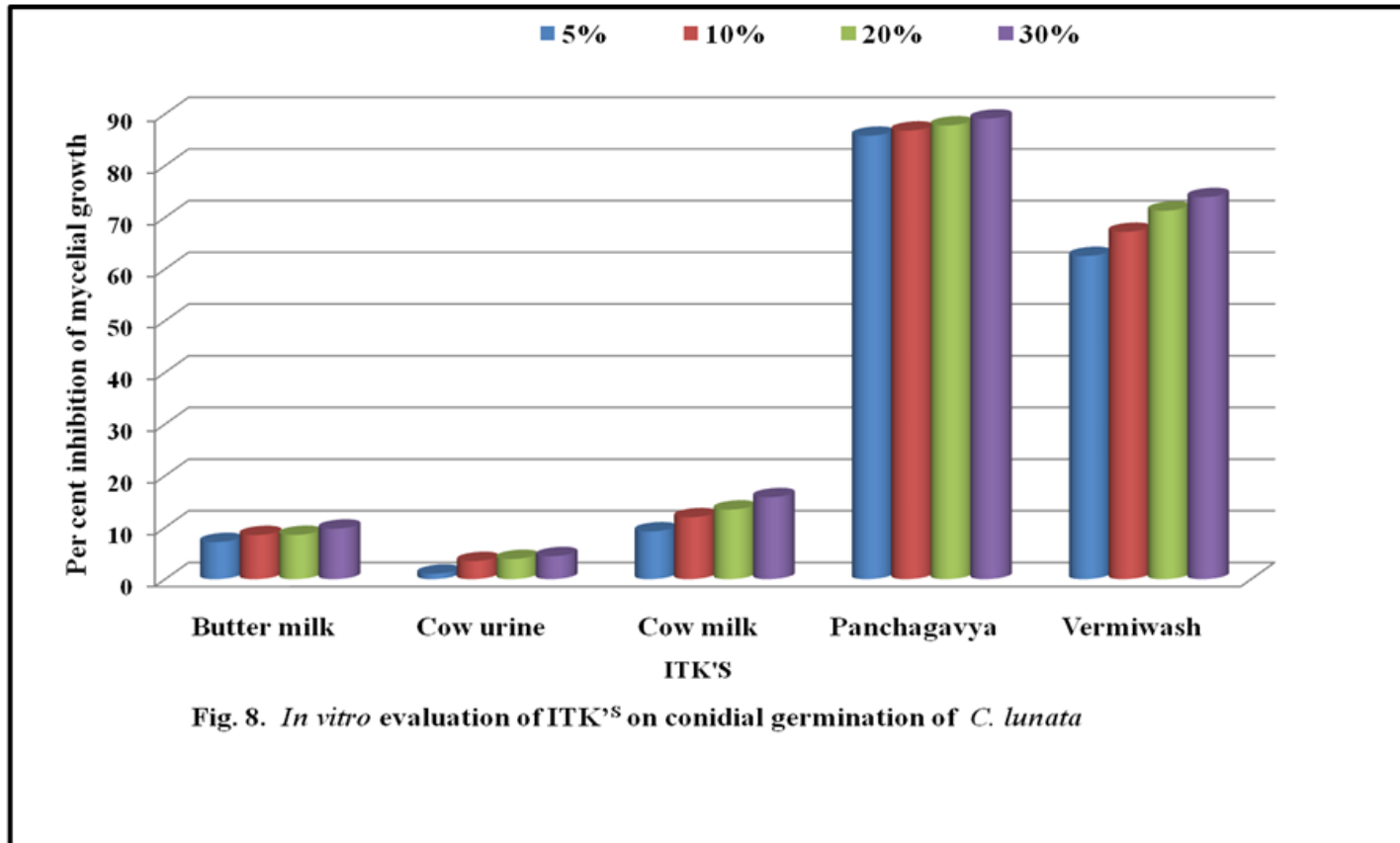
The effect of ITK^S on conidial germination was significant. Five test ITK^S increased the inhibition of conidial germination of *C. lunata* at 5 %, 10 per cent, 20 per cent and 30 per cent concentrations. At 5 per cent concentration, maximum inhibition was noticed in panchagavya (85.78%) followed by vermiwash (62.52 %) and the next best was cow milk (9.25 %) followed by butter milk (7.18%). Least inhibition was noticed in cow urine (1.04 %). At 10 per cent concentration, similar trends were observed. At 10 per cent concentration maximum inhibition was noticed in panchagavya (86.78 %) followed by vermiwash (67.19 %). Next best was cow milk (11.46%) followed by butter milk (8.53%). Least inhibition was noticed in cow urine (3.49 %). At 20 per cent concentration, similar trends were observed. Maximum inhibition was noticed in panchagavya (87.78 %) followed by vermiwash (71.29 %). Next best was cow milk (13.46%) followed by butter milk (8.56 %). Least inhibition was noticed in cow urine (3.90 %).

At 30 per cent concentration, panchagavya recorded the maximum inhibition of conidial germination of 89.09 per cent followed by vermiwash (73.91 %). Cow milk was found next best (15.85 %). Least inhibition was observed in cow urine (4.44%).

Table 10. *In vitro* evaluation of ITK^S on conidial germination of *C. lunata*

Sl. No.	ITK ^S	Percent inhibition of conidial germination at different concentration (%)				Mean
		5	10	20	30	
1	Butter milk	7.18(15.54)*	8.53(16.98)	8.56(17.01)	9.77(18.21)	8.95(17.41)
2	Cow urine	1.04(05.85)	3.49(10.77)	3.90(11.39)	4.44(12.16)	3.94(11.45)
3	Cow milk	9.25(17.71)	11.98(20.25)	13.46(21.52)	15.85(23.46)	13.76(21.78)
4	Panchagavya	85.78(67.85)	86.78(68.68)	87.78(69.54)	89.09(70.71)	87.88(69.63)
5	Vermiwash	62.52(52.25)	67.19(55.06)	71.29(57.60)	73.91(59.28)	70.80(57.29)
Mean		33.15(32.16)	35.59(36.63)	37 (37.46)	38.61(38.61)	37.07(37.51)
		ITK ^S (I)		Concentration (C)	IxC	
S.Em±		1.52		1.36	3.04	
C.D.at 1%		5.66		5.06	NS	

* Arc sine transformed values



Irrespective of ITK concentration, panchagavya (87.35 %) was found to be the best in inhibiting spore germination and followed by vermiwash (68.72 %). Next best was cow milk (12.63 %) followed by butter milk (8.51 %). Least inhibition was noticed in cow urine (3.21 %).

4.4.2 Evaluation of spray schedule

A field experiment was conducted in randomized block design with three replications during *kharif* 2014 at Agricultural Research Station, Arabhavi, University of Agricultural Sciences, Dharwad, on integrated management of *Curvularia* leaf spot using susceptible genotype CP 818. Based on *in vitro* evaluation results, effective and economically viable systemic fungicide (hexaconazole), non systemic fungicide (carbendazim 12% WP + mancozeb 63% WP), commercially available botanical (wanis) and ITK (panchagavya) were included in the spray schedule as mentioned in the “Material and Methods” and the results obtained are presented in Table 11a, Plate 7a and 7b.

The data presented in Table 11a indicated that significant differences among the spray schedule was evident in respect of per cent disease index. Among the eight spray schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded the least per cent disease index of 42.35 which was significantly superior to other spray schedule combinations. Next best schedule was hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent (T₅) and it was significantly superior to other spray schedule combinations. The spray schedules combinations carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5 per cent (T₆), carbendazim + mancozeb @ 0.2 per cent- carbendazim + mancozeb @ 0.2 per cent (T₄), and hexaconazole @ 0.1 per cent - panchagavya @ 10 per cent (T₇) were recorded 55.33, 56.02 and 61.40 per cent disease index, respectively. However, all these treatments were on par with each other. The unsprayed control (T₉) recorded significantly highest per cent disease index of 75.91.

Table 11a. Evaluation of spray schedule involving fungicide, commercially available botanical and ITK on Curvularia leaf spot of maize during *kharif* 2014

Spray schedule	Percent Disease Index (PDI)	Grain yield (q/ha)	Per cent increase in grain yield over unsprayed control	100 grain weight (g)	Per cent increase in 100 grain weight over unsprayed control	Stover yield (t/ha)	Per cent increase in Stover yield over unsprayed control	B:C ratio
T ₁ : Wanis @ 0.5%- Wanis @ 0.5%	62.54 (52.26)*	57.47	10.34	37.33	6.65	7.00	11.11	2.40
T ₂ : Panchagavya @ 10%- Panchagavya @ 10%	68.66 (55.96)	60.42	16.01	36.40	4.00	6.55	3.96	2.43
T ₃ : Hexaconazole @0.1%- Hexaconazole @ 0.1%	42.35 (40.60)	79.58	52.80	41.33	18.08	8.02	27.30	3.81
T ₄ : Carbendazim + mancozeb @ 0.2%- Carbendazim + mancozeb @ 0.2%	56.02 (48.46)	64.90	24.61	38.66	10.45	7.08	12.38	2.71
T ₅ : Hexaconazole@0.1%- Wanis @ 0.5%	53.15 (46.80)	66.01	26.74	40.00	14.28	7.92	25.71	2.81
T ₆ : Carbendazim + mancozeb @ 0.2%- Wanis @ 0.5%	55.33 (48.06)	67.08	28.80	39.66	13.31	7.38	17.14	2.81
T ₇ : Hexaconazole @ 0.1%- Panchagavya @ 10%	61.40 (51.59)	61.67	18.41	38.00	8.57	7.05	11.90	2.69
T ₈ : Carbendazim + mancozeb @ 0.2%- Panchagavya @10%	65.72 (54.16)	59.97	15.14	37.17	6.60	6.67	5.87	2.42
T ₉ : Unsprayed control	75.91 (60.61)	52.08	-	35.00		6.30	-	2.18
S.Em±	3.03	1.22		1.18		0.215		
C.D. at 5 %	9.11	3.65		3.54		0.644		

* Arc sine transformed values.

Cost of grain Rs.1240/q, cost of Stover Rs.660/t, cost of fungicide/plant based products in Rs.Kg or l- hexaconazole(580), carbendazim + mancozeb(600), wanis(450) and panchagavya (Rs.1500/ha). Quantity of spray solution used for two sprays per hectare Rs – 1250l. Cost of cultivation Rs.-20000/ha

4.4.2.1 Effect of spray schedule on grain yield, 100 grain weight and stover yield

The spray schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded significantly the highest grain yield of 79.58 q ha⁻¹ over other spray schedule. Next best spray schedule was carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5 per cent (T₆) which has recorded 67.08 q ha⁻¹ and it was on par with spray schedule hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent (T₅, 66.01 q ha⁻¹) and carbendazim + mancozeb @ 0.2 per cent - carbendazim + mancozeb @ 0.2 per cent (T₄, 64.90 q ha⁻¹). Grain yields in the spray schedule hexaconazole @ 0.1 per cent - panchagavya @ 10 per cent (T₇, 61.67 q ha⁻¹), carbendazim + mancozeb @ 0.2 per cent - panchagavya @ 10 per cent (T₈, 59.97 q ha⁻¹) and wanis @ 0.5 per cent - wanis @ 0.5 per cent (T₁, 57.47 q ha⁻¹) were on par with each other. Significantly the lowest grain yield of 52.08 q ha⁻¹ was recorded in unsprayed control (T₉).

Highest per cent increase in grain yield over unsprayed control was recorded in the spray schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (52.80) followed by carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5 per cent (28.80), hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent (26.74), and carbendazim + mancozeb @ 0.2 per cent - carbendazim + mancozeb @ 0.2 per cent (24.61). Least per cent increase in grain yield over unsprayed control was observed in spray schedule wanis @ 0.5 per cent - wanis @ 0.5 per cent (10.34).

Almost similar trend was observed with respect to 100 grain weight. Hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded highest grain weight of 41.33 g and followed by hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent (T₅, 40.00 g), carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5 per cent (T₆, 39.66 g), carbendazim + mancozeb @ 0.2 per cent - carbendazim + mancozeb @ 0.2 per cent (T₄, 38.66 g) followed by hexaconazole @ 0.1 per cent - panchagavya @ 10 per cent

(T₇, 38.00 g) and were on par with each other. Least 100 grain weight of 35.00 g was recorded in unsprayed control.

Highest per cent increase in 100 grain weight over unsprayed control was recorded in the spray schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (18.08) and least was in panchagavya @ 10 per cent- panchagavya @ 10per cent (4.00).

The spray schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded highest stover yield of 8.02 t ha⁻¹ over other spray schedule. Next best spray schedule was hexaconazole @ 0.1 per cent- wanis @ 0.5per cent (T₅, 7.92 t ha⁻¹) which is on par with the spray schedule carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5per cent (T₆, 7.38 t ha⁻¹). Significantly the lowest stover yield of 6.30 t ha⁻¹ was recorded in unsprayed control (T₉).

Highest per cent increase in stover yield over unsprayed control was recorded in the spray schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (27.30) and least was in Panchagavya @ 10 per cent- Panchagavya @ 10 per cent (3.96).

4.4.2.2 Benefit: Cost ratio

The benefit cost ratio has been worked out for different spray schedule and presented in Table 11. The highest B: C was obtained with spray schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (1:3.81) followed by hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent and carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5per cent both were recorded B:C (1:2.81). Most of the remaining spray schedules treatments, T₄, T₇, and T₂ recorded next highest B: C of 1: 2.71, 1:2.69, 1: 2.43 and 1: 2.42, respectively. Least B: C of 1:2.18 was recorded in unsprayed control.

4.4.2.3 Effect of spray schedule on starch and oil content

The difference in both oil and starch content in the grains in different spray schedule was non significant (Table.11b). However , numerically the spray schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded highest oil

Table 11b. Effect of spray schedule on starch and oil content in grains as influenced by Curvularia leaf spot of maize

Spray schedule	Percent Disease Index (PDI)	Percent oil content in grains	Per cent increase in oil content over unsprayed control	Percent starch content in grains	Per cent increase in starch content over unsprayed control
T ₁ : Wanis @ 0.5%- Wanis @ 0.5%	62.54 (52.26)*	4.53 (12.29)	7.09	70.70 (57.23)	0.81
T ₂ : Panchagavya @ 10%- Panchagavya @ 10%	68.66 (55.96)	4.47 (12.20)	5.67	70.63 (57.19)	0.71
T ₃ : Hexaconazole @0.1%- Hexaconazole @ 0.1%	42.35 (40.60)	4.83 (12.70)	14.18	70.97 (57.40)	1.19
T ₄ : Carbendazim + mancozeb @ 0.2%- Carbendazim + mancozeb @ 0.2%	56.02 (48.46)	4.47 (12.20)	5.67	70.80 (57.29)	0.95
T ₅ : Hexaconazole @ 0.1%- Wanis @ 0.5%	53.15 (46.80)	4.60 (12.38)	8.74	70.90 (57.35)	0.23
T ₆ : Carbendazim + mancozeb @ 0.2%- Wanis @ 0.5%	55.33 (48.06)	4.50 (12.25)	6.38	70.80 (57.29)	0.95
T ₇ : Hexaconazole @ 0.1%- Panchagavya @ 10%	61.40 (51.59)	4.30 (11.97)	1.65	70.67 (57.21)	0.76
T ₈ : Carbendazim + mancozeb @ 0.2%- Panchagavya @10%	65.72 (54.16)	4.37 (12.06)	3.30	70.67 (57.21)	0.76
T ₉ : Unsprayed control	75.91 (60.61)	4.23 (11.87)	-	70.13 (56.87)	-
S.Em±	3.03	0.28		0.33	
C.D. at 1 %	9.11	NS		NS	

* Arc sine transformed values



Hexaconazole @ 0.1% - Hexaconazole @ 0.1%



SAAF (Carbendazim + Mancozeb @ 0.2%) - SAAF(Carbendazim + Mancozeb @ 0.2%)



Plate 7a: Severity of Curvularia leaf spot in different spray schedule



Hexaconazole @ 0.1% - Wanis @ 0.5%



Carbendazim + Mancozeb @ 0.2% - Wanis @ 0.5%



Plate 7b: Severity of Curvularia leaf spot in different spray schedule

content of 4.83per cent and it was 14.18 per cent more over the unsprayed control. Similar trend was also observed with respect to starch content where in the spray schedule hexaconazole@ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded highest starch content of 70.97per cent which is 1.19 per cent more over the unsprayed control.

4.5 Screening of maize genotypes to *Curvularia* leaf spot

Fifty five maize genotypes were screened during *kharif* 2014 against *C. lunata* under artificial epiphytotic condition in the field to identify the resistant sources as described in “Material and Methods” and the data are presented in Table 12.

The results revealed that, among 55 genotypes screened, none was found immune or highly resistant, one was found moderately resistant (CI 4), ten genotypes showed moderately susceptible reaction (KDMI 6, NAH 137, African Tall, MAH 974, MAH 957, GH 110204, KDMI 10, CM 111, GH 110145 and Pop corn), 25 genotypes were susceptible (ARYP 81, ARYP 36, ARYP 64, ARYP 60, ARYP 6, ARYP 43, ARYP 28, ARYP 30, ARYP 68, ARYP 53, ARYP 76, ARYP 78, ARYP 47, ARYP 14, ARYP 2, NAH 1137, NAC 6004, GPMH 1111, GPMH 1101, GH 1043, DMH 100-3, BGMH 2, BGMH 1, CM 501 and CI 5) and remaining 19 genotypes were found highly susceptible (ARYP 83, ARYP 82, ARYP 33, ARYP 53, ARYP 47, ARYP 63, ARYP 74, ARYP 46, ARYP 24, ARYP 23, ARYP 39, ARYP 25, ARYP 79, ARYP 61, NAH 2049, Thaipop, SKV 50 , NAC 6002 and Madhuri).

Table 12. Screening of maize genotypes against *Curvularia* leaf spot disease during *kharif* 2014

Sl. No	Disease grade	Disease reaction	Genotypes	No. of genotypes
1	0	Immune	-	Nil
2	1	Resistant	-	Nil
3	3	Moderately Resistant	CI 4	1
4	5	Moderately susceptible	KDMI 6, NAH 137, African Tall, MAH 974, MAH 957, GH 110204, KDMI 10, CM 111, GH 110145 and Pop corn	10
5	7	Susceptible	ARYP 81, ARYP 36, ARYP 64, ARYP 60, ARYP 6, ARYP 43, ARYP 28, ARYP 30, ARYP 68, ARYP 53, ARYP 76, ARYP 78, ARYP 47, ARYP 14, ARYP 2, NAH 1137, NAC 6004, GPMH 1111, GPMH 1101, GH 1043, DMH 100-3, BGMH 2, BGMH 1, CM 501 and CI 5	25
6	9	Highly susceptible	ARYP 83, ARYP 82, ARYP 33, ARYP 53, ARYP 47, ARYP 63, ARYP 74, ARYP 46, ARYP 24, ARYP 23, ARYP 39, ARYP 25, ARYP 79, ARYP 61, ARYP 33, NAH 2049, Thaipop, SKV 50 and NAC 6002	19

5. DISCUSSION

Maize (*Zea mays* L.) as the source of food, forage and processed products for industry, is an important cereal (Chulze, 2010). It is cultivated widely throughout the world and has the highest production among all the cereals. It is an important staple food in many countries and is also used in animal feed and many industrial applications. The crop has tremendous genetic variability, which enables it to thrive in tropical, subtropical and temperate climates. United States is the largest maize producer and also has a large surplus, which also makes it the largest maize exporter. Brazil, Ukraine and Argentina are the other key maize producing countries behind United States. The four countries together account for 80-85 per cent of the total exports in maize. Maize is grown throughout the year in India. It is predominantly a *kharif* crop with 85 per cent of the area under cultivation in the season.

In India, it is consumed both as food and fodder. It has got immense potential and hence called as 'Miracle crop' and also called as 'Queen of cereals'. In the future, maize demand is expected to increase, mainly because it is used by larger population as human food and because of its increased consumption as feed in poultry for animal protein. Besides multiple uses and several products derived from maize crop, it can contribute to diet diversification and improved nutrition in human beings through exploitation of quality maize protein (Singhal,2003).

Maize is being plagued by an array of diseases which include the leaf spot of maize caused by *Curvularia lunata* (Singh *et al.*, 2002) exhibiting symptoms as small chlorotic spots which gradually expand into round or oval shaped lesion surrounded by a wide translucent straw yellow halo. A number of lesions can be connected leading to the formation of leaf necrosis. This causes significant damage to maize up to 60% due to great loss of photosynthetic area of the crop (Hai *et al.*, 1995; Huang *et al.*, 2004; Hua *et al.*, 2006).

Curvularia leaf spot (CLS) of maize in Karnataka is gaining economic importance in recent years. This disease is emerging as one of the major production constraints in various maize growing regions of the State. In spite of its destructive nature not much work with respect to different aspects has been carried out. Hence, the present study was undertaken considering different aspects like survey of the disease to know the disease severity in different districts of northern Karnataka. The lack of information on studies on loss assessment and management aspects of the disease made an impetus to undertake the present investigation. Hence, detailed investigations were carried out *in vitro* and in the field on various aspects of loss assessment, integrated management and identification of resistant sources have been attempted and the results obtained are discussed here under.

5.1 Survey for severity of the disease

In the present study, an intensive roving survey was conducted in different maize growing districts of northern Karnataka *viz.*, Belagavi, Bagalkot and Vijayapur during *kharif* 2014 to know the disease situation.

The survey reports revealed that CLS severity varied from one locality to another, because of cultivation of different genotypes, environmental conditions prevailing, cropping pattern and inoculum build up. The disease severity varied from low (2.44%) in Vijayapur district to high (9.02%) in Belagavi district where maize crop was grown under irrigated condition. When individual taluk were compared, Saundatti (8.97%), Gokak (9.83%), and Raibhag (8.27%) recorded the highest severity during *kharif* 2014. In the present study higher severity of Curvularia leaf spot in all the taluks of Belagavi district may be due to high relative humidity within the crop canopy as the crop was grown under irrigated condition. Harlapur (2014) in his survey during *kharif* and *rabi*/summer 2013 reported the high severity of Curvularia leaf spot in Kalaghatagi and Dharwad taluks of Dharwad district and also in Davanagere and Haveri districts and opined that higher severity in these areas may be attributed to high rain fall and high relative humidity.

5.2 Assessment of crop losses due to *Curvularia* leaf spot

The crop losses varied significantly from genotype to genotype. The losses were directly proportional to the disease severity. The higher per cent disease index observed in the genotypes in turn reflected on the magnitude of the loss. Thus, it may be concluded that the improved hybrids, because of higher *per se* yield potential were able to possess greater tolerance or resistance and withstand the debilitating effect of disease leading to minimum / lower loss.

In the present study, besides significant losses (19.03-41.00%) in grain yield, considerable percent losses were also observed with other parameters like 100 grain weight (3.61-9.64%), stover yield (3.47-33.68%), oil content (1.05-11.95%) and starch content (0-1.41%) in different genotypes under unprotected treatment. The differences in maize yield differed significantly with protected block and it recorded higher maize yield (90.46 q/ha) compared to unprotected block (70.09 q/ha) and higher to an extent of 22.52 per cent (Table 3). This improvement may be due to spraying of hexaconazole @ 0.1 per cent in protected block. This technique also resulted in increase in yield attributing characters *viz.*, 100 grain weight, stover yield, starch and oil content.

This suggests the need for avoiding timely losses due to CLS disease in maize. Therefore indicated that, the yield loss not only depends on the level of severity alone but also on disease tolerance of genotype. It shows that the loss in yield at the same level of disease severity may vary from genotype to genotype. Therefore, host plant resistance is an important component which is quite effective in mitigating the losses caused by the disease. Upto 60% losses in grain yield of maize due to *Curvularia* leaf spot have been reported both in China and India (Hai *et al.*, 1995 and Grewal and Payak., 1976). Cui and Sun (2012) estimated that yield loss in lotus was 10 to 15% due to *Curvularia* leaf spot.

5.3 Integrated management of *Curvularia* leaf spot

5.3.1 *In vitro* evaluation of fungicides, commercially available botanicals and indigenous technology knowledge against *C. lunata*

5.3.1.1 *In vitro* evaluation of fungicides

In vitro evaluation of newly released fungicides is very much necessary before they are planned to be used under field experiments. In the present study, *in vitro* evaluation of systemic fungicides at 0.05 per cent concentration, maximum inhibition was noticed in three chemicals viz., hexaconazole, propiconazole and triadimefon (100.00%) followed by difenconazole (92.36 %). Least inhibition of mycelial growth was noticed in carbendazim (28.33 %) followed by thiophanate methyl (31.67 %) and at 0.1 percent concentration maximum inhibition was noticed in four chemicals viz., difenconazole, hexaconazole, propiconazole and triadimefon (100.00%). Least inhibition of mycelial growth was noticed in carbendazim (29.72 %) and thiophanate methyl (47.21 %). The effectiveness of systemic fungicides, difenconazole and propiconazole against *C. lunata* has been reported by Sumangala *et al.* (2008).

Four non systemic fungicides at 0.2 per cent concentration, maximum inhibition was observed carbendazim + mancozeb and propineb (100.00%) followed by mancozeb (84.44 %). Least inhibition of mycelial growth was noticed in chlorothalonil (28.15 %). At 0.3 per cent concentration maximum inhibition was noticed in carbendazim + mancozeb and propineb (100.00%) followed by mancozeb (90.74 %). Least inhibition of mycelial growth was noticed in chlorothalonil (70.56 %). The effectiveness of non systemis fungicides, mancozeb against *C. lunata* has been reported by Sumangala *et al.* (2008). Dithane-M 45, a fungicide performed significantly superior in the control of *C. lunata* (Njoku *et al.*, 2000 and Yan *et al.*, 2003).

5.3.1.2 *In vitro* evaluation of commercially available botanicals

Continuous use of chemical fungicides in the management of diseases also brought new problems along with them and alarming among them are the pollution of air, water,

soil residual toxicity and development of resistance in pathogen against chemical, there by the need to apply them with their escalating prices and harmful effects on non target organisms. Botanicals are ecofriendly renewable, inexhaustible, indigenously available and easily assessable largely non phytotoxic, thus redially biodegradable, relatively cost effective and hence constitute suitable plant protection in the strategy of integrated disease management. Hence screening of botanicals for their effective and antifungal activity against the pathogen is essentially required to minimize the use of fungicides and to consider as one of the component in the integrated disease management (Khadar, 1999).

In the present study, *in vitro* evaluation of commercially available botanicals was carried out with respect to inhibition of mycelial growth of *C. lunata* at different concentrations (0.25, 0.5 and 1 %). Maximum inhibition of mycelial growth irrespective of the botanical concentration was noticed with wanis (95.83 %) followed by nimbicidine (67.68 %) and neem gold (66.24 %) whereas the least inhibition of mycelial growth was observed in soldier (13.79 %) and sainik (37.83 %). These results are in agreement with Bisht *et al.* (2013) who studied the effect of botanicals on mycelial growth of *C. lunata* revealed that amongst the plant extracts, lantana was highly effective @ 15 per cent (86.76%) and 20 per cent (89.49 %) followed by morphankhi @ 5 per cent (83.53 %) and 10 per cent (85.88%). And also by Hurali (2008) who tested 25 plant extracts on urediospore germination of *Phakopsora pachyrhizi* and found that *Allium sativum*, *Azadirachta indica* and *Amaranthus viridis* at 5 and 10 per cent concentration showed maximum per cent inhibition. The inhibitory action of NSKE may be due to Azadirachtin present in seed kernels which retards the growth and activation of the pathogen.

5.3.1.3 *In vitro* evaluation of ITK^s

In vitro evaluations are very much necessary before they are planned to be used under field experiments. In the present investigation five different ITK's (panchagavya, vermiwash, cow urine, butter milk and cow milk) are evaluated against spore germination of *C. lunata* at different concentrations. All the ITK^s used have shown antifungal activity

but the extent of activity was varied with different ITK dilutions and their interactions are concerned. However, the maximum inhibition of spore germination was observed in panchagavya followed by vermiwash at 30 per cent. Whereas, butter milk and cow urine treatments have shown least per cent inhibition.

In the present study, *in vitro* evaluation of ITK^{'s} was carried out with respect to inhibition of spore germination of *C. lunata* at different concentrations (5, 10, 20 and 30 %). At 30 per cent concentration, maximum inhibition was noticed in panchagavya (89.09 %) followed by vermiwash (73.91 %). These results coincide with Sumangala and Patil (2007) evaluated *in vitro* for its antifungal activity against *C. lunata* in rice, which found to be the dominant pathogen in causing grain discolouration. Panchagavya resulted in 86.30 per cent inhibition of mycelial growth and 95.9 per cent of spore germination of *C. lunata*. Seed treatment with panchagavya further enhanced the seed germination with 90.7 per cent and vigor index of 1036.

5.3.2 Evaluation of spray schedule

The concept of organic farming and ecofriendly management encouraged the plant protection specialists to go for the use of plant extracts for the management of pest and diseases. This can also avoid the pollution of air, water and soil. Use of chemicals has been discouraged. Plant extracts which were previously known for their antifungal and antibacterial nature were evaluated against *C. lunata* following poison food technique. Results were encouraging so as to use the plant extracts as a component in development of IDM strategies against Curvularia leaf spot.

The fungicidal spectrum of neem (*A. indica*) has already been investigated by Singh and Pande (1966) and reviewed in detail by Parveen and Alam (1993). Antifungal properties of *A. indica* were also established by Singh *et al.* (1984) and Usman *et al.* (1991). The chemical basis of this antifungal activity has been attributed to the presence of oil in the plant parts of *A. indica* (Singh and Dwivedi, 1990).

In evaluation of fungicides, new generation of systemic molecules were tested in both in laboratory and field conditions along with recommended fungicides to know their relative efficacy against pathogen. Cultivation of resistant genotypes is an effective and cheapest method to combat the diseases as compared to chemical control.

The experiment spray schedule was made by making combination of chemical, commercially available botanical, and ITK^S and in the spray schedule was taken by chemical followed by chemical and chemical followed by commercially available botanical and chemical followed by ITK^S to know the individual and their effect of combinations spray and reduce load of chemicals hazards on environment. In the present investigation, the lowest percent disease severity was recorded in the spraying schedule hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (42.35 %) followed by hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent (53.15 %) and carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5 per cent (55.33%). The highest percent disease severity over unsprayed control was recorded in panchagavya @ 10 per cent - panchagavya @ 10 per cent (68.66 %). Whereas hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded highest seed yield of 79.58q ha⁻¹ and followed by other spray schedule treatments, T₆ (67.08 q ha⁻¹), T₅ (66.01q ha⁻¹) and except unsprayed control which was recorded 52.08 q ha⁻¹ (Table 11a). Similar trend were observed in case of 100 grain weight. Hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded highest 100 grain weight of 41.33 g and it was statistically on par with hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent (40.00 g), carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5 per cent (39.66 g) and carbendazim + mancozeb @ 0.2 per cent - carbendazim + mancozeb @ 0.2 per cent (38.66 g). Next best schedule which recorded higher grain weight was hexaconazole @ 0.1 per cent - panchagavya @ 10 per cent (38.00 g). Unsprayed control recorded significantly the lowest grain weight of 35.00 g.

Similar trend was observed in case of stover yield. Hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (T₃) recorded highest grain weight of 8.02 t ha⁻¹ and was

statistically on par with with hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent (7.92 t ha^{-1}), carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5 per cent (7.38 t ha^{-1}) and carbendazim + mancozeb @ 0.2 per cent - carbendazim + mancozeb @ 0.2 per cent (7.04 t ha^{-1}). Unsprayed control recorded significantly the lowest stover yield of 6.30 t ha^{-1} .

The difference in oil and starch content in different spray schedule combinations was found non significant. The highest B: C was obtained with spray schedule, hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent (1:3.8) by hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent and carbendazim + mancozeb @ 0.2 per cent - wanis @ 0.5 per cent (1:2.81). Remaining spray schedule treatments, T₄, T₇ and T₂ recorded next highest B: C of 1: 2.71, 1:2.69 and 1: 2.43 respectively (Table 11a).

These results are in agreement with Hurali (2008) who confirmed least disease severity of 26.07 per cent in hexaconazole alone spray followed by cristol 56SL – hexaconazole – cristol 56SL (27.71 %) spray schedule. Whereas, neem oil – hexaconazole – neem oil spray schedule recorded maximum (23.16 q ha^{-1}) seed yield followed by cow milk – hexaconazole – cow milk (22.66 q ha^{-1}) spray schedule against soybean rust. The present findings are also in agreement with Patil (2008) who reported that among the seven commercially available plant based products tested *viz.*, neem oil, margotricure, nimbidine and neem gold at 0.5 per cent and wanis at 1.0 per cent, sprayed thrice at an interval of 10 days starting from the onset of disease were found promising in reducing the soybean rust severity with significant increase in seed yield and 100 seed weight. Among the botanicals highest B: C (2.74) was recorded in neem oil followed by margotricure (1.12) and nimbidine (0.96).

5.4 Screening of maize genotypes to Curvularia leaf spot disease

Management of the disease through host plants resistance has been the best choice in all crop improvement programmes. Utilization of resistant cultivars in farming system is the most simple, effective and economical method in the management of plant diseases.

Besides this, these resistant cultivars conserve natural resources and reduce the cost, time and energy when compared to the other methods of disease management. In the present study 55 maize genotypes were screened under artificial epiphytotic field condition for resistance against *Curvularia* leaf spot. The study revealed that none of the genotypes were found to be immune or highly resistant and one genotype was show moderately resistant, ten genotype showed moderately susceptible, 25 were susceptible and remaining 19 were highly susceptible. Choudhary *et al.*(2011) evaluated 35 maize inbred lines against *C. lunata* and identified five lines *viz.*, EI 460, EI 585, EI 582, EI 586-1 and LM 10 as resistant, six as moderately resistant, 14 as susceptible and remaining ten lines as highly susceptible. The screening of maize genotypes to different diseases at All India Coordinated Maize Improvement Project centers in India during *kharif* 2010 to 2012 has yielded 77 lines with resistant to moderately reaction one or more diseases. Two lines *viz.*, WINPOP-3 and HKI 1040-5 have shown resistant against reaction to *Curvularia* leaf spot (Anon., 2013).

Thus the promising high yielding CLS resistant maize genotypes identified through this investigation can be deployed in disease endemic areas to aim for sustainable productivity or can be used in resistance breeding programme.

Future line of work

- i. Survey and surveillance of the disease have to be undertaken every year in future to observe rhythmic changes in the severity of the disease and also the status and regional severity of the disease.
- ii. Morphological, pathogenic and molecular variation of *C. lunata* across the region to be assessed.
- iii. Studies on survival structures of the fungus are needed for better understanding of the life cycle of *C. lunata*
- iv. Molecular based PCR techniques should be standardized for the accurate and early diagnosis of seed-borne fungal infection of maize in the infected grain samples.
- v. Epidemiological investigations including aerobiological studies, agro-meteorological relationships and disease forecasting of the pathogen.

6. SUMMARY AND CONCLUSIONS

Maize (*Zea mays* L.) is one of the most important cereal crops of the world and contributes to food security in most of the developing countries. In India, maize is emerging as the third most important crop after rice and wheat. Its importance lies in the fact that it is not only used for human food and animal feed but at the same time it is also widely used for corn starch industry, corn oil production, baby corns etc.

Maize crop is being affected by many biotic and abiotic stresses which have led to drastic reduction in yield. Curvularia leaf spot (CLS) of maize caused by *Curvularia lunata* is considered to be one of the foliar disease worldwide. In Karnataka during recent years its severity is on increasing trend as most of the private and public hybrids grown in farmers field are found to be susceptible to Curvularia leaf spot.

In spite of its destructive nature, not much work with respect to different aspects such as its distribution, loss estimation and management of the disease has been carried out. Hence, the present study was undertaken considering different aspects like survey of the disease to know the disease severity in different districts of northern Karnataka, studies on loss assessment in different popular public and private maize hybrids due to the disease, identification of resistant sources and *in vitro* evaluation of fungicides, commercially available botanicals and indigenous technology knowledge against *C. lunata* and finally development of effective spray schedule involving cost effective fungicide, botanical and ITK^s in an integrated approach.

The survey during *kharif* 2014 revealed that, the disease was noticed in varying intensities in three districts surveyed. Maximum disease severity was noticed in Arabhavi village (10.75 %) of Gokak taluka followed by Yaragatti village (10.03 %) of Belagavi. The disease severity was higher in Gokak taluk (9.83 %) followed by Saundatti (8.97 %) and Jamakhandi (8.75 %) taluk. The congenial condition like high temperature, relative humidity and rainfall must have helped in building up of disease in Belagavi (9.02 %) followed by Bagalkot (5.31 %) districts.

In loss assessment studies among different maize genotypes to CLS, irrespective of the fungicidal spray significantly higher per cent disease index of 38.27 recorded in the genotype CP 818 which was on par with Arjun (36.20).

Among different genotypes, irrespective of the fungicidal spray higher grain yield recorded was in Mograon (80.32 q ha⁻¹) and highest 100 grain weight was recorded (40.75 g) in the genotype NK 6240. Stover yield (8.00 q ha⁻¹) was highest in DKC 9133. Least grain yield (34.07 q ha⁻¹) and 100 grain weight (33.00 g) were recorded in Arjun.

Irrespective of the spray highest decrease in percent disease index was recorded in the genotype Prabal (95.98 %) followed by Mograon (94.50). The lowest decrease in percent disease index was recorded in Super 900M (81.85) and the highest percent loss in grain yield was recorded in the genotype MAH 957 (41.00) followed by Arjun (39.99). Lowest per cent loss in grain yield was recorded in the genotype DKC 9133 (19.03). Similarly highest percent loss in 100 grain weight of 9.64 was recorded in the genotype Shimsha 517 followed by Arjun (8.57). Lowest percent loss in grain weight was recorded in the genotype NK 6240 (3.61). Similarly trend highest per cent loss in stover yield was recorded in the genotype DKC 9133 (33.68) and lowest was in 900M Gold and also highest per cent loss in starch content was recorded in the genotype Shimsha 517 (1.41). Prabal genotype recorded no loss in starch content and highest percent loss in oil content of 11.95 was recorded in the genotype 900M Gold followed by NK 6240(9.59). Lowest percent loss in oil content was recorded in the genotype Kaveri 244 (1.05).

Among systemic fungicide irrespective of concentration hexaconazole, propiconazole and triadimefon were found to be the best in inhibiting the mycelial growth (100.00%) and remain on par with difenconazole at 0.025 per cent (91.67 %). Among the non systemic fungicide carbendazim + mancozeb was found to be the best in inhibiting the mycelial growth (91.98%) and remain on par with propineb (91.30 %). Maximum inhibition irrespective of the botanical concentration was noticed with wanis (95.83 %) followed by nimbicidine (67.69 %) and neemgold (66.24 %) whereas least inhibition of

mycelial growth was observed in soldier (13.79 %) and neem oil (28.88 %). Irrespective of ITK concentration panchagavya (87.88 %) was found to be the best in inhibiting spore germination followed by vermiwash (70.80 %). Significantly least inhibition was noticed in cow urine (3.94%).

Integrated management of the disease involving economically viable and effective fungicides, commercially available botanical and indigenous technology knowledge using highly susceptible genotype were carried out at Agricultural Research Station (ARS), Arabhavi during *kharif* 2013-14.

Among the different spray schedules evaluated hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent reduced the disease severity of CLS effectively and also enhanced the yield, 100 grain weight and stover yield. Starch and oil content shows no significant difference. Hexaconazole @ 0.1 per cent - waxis @ 0.5 per cent was the next best schedule in disease control as well as in increasing grain yield, 100 grain weight and stover yield. The highest B: C was obtained in hexaconazole @ 0.1 per cent - hexaconazole @ 0.1 per cent spray schedule (1:3.8).

Among the 55 genotypes screened, none was found immune or highly resistant, one was found moderately resistant (CI 4), ten genotypes showed moderately susceptible reaction, 25 genotypes were susceptible and remaining 19 genotypes were highly susceptible.

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* Original not seen

Appendix-I Weather data of during crop period at Agriculture Research Station, Arabhavi for the year 2014

Month	Temperature °C				RH%	Actual		Normal (15 Yrs)		Evaporation (mm)
	Min.	Min Nor	Max.	Max. Nor.		Rainfall (mm)	No. of rainy day	Rainfall (mm)	No. of rainy day	
January	14.45	9.30	28.85	29.40	69.20	0.00	0	0.3	0	3.30
February	15.01	10.20	31.19	30.90	64.90	0.00	0	1.1	0	3.77
March	17.35	16.00	34.57	33.10	63.10	6.00	1	6.4	0	3.88
April	20.10	18.20	37.50	35.10	65.60	5.20	1	22.60	1	6.00
May	26.90	19.90	36.30	34.40	64.40	93.80	5	33.0	2	8.70
June	22.30	20.90	33.70	29.10	73.50	63.00	2	78.90	6	5.80
July	21.60	19.90	30.60	28.30	80.70	85.30	9	55.90	6	3.10
August	22.20	19.10	28.70	28.50	84.40	82.10	11	51.50	5	1.80
September	20.40	18.30	29.00	29.20	87.90	19.00	2	66.90	6	3.70
October	19.60	14.70	31.60	30.00	73.60	86.30	3	99.00	6	3.00
November	16.70	19.96	29.80	29.26	70.8	37.70	3	28.10	2	3.50
December	17.80	16.15	28.40	28.16	71.89	19.30	1	5.40	0	2.50
Total						497.7	38	449.3	34	49.05

CURVULARIA LEAF SPOT OF MAIZE AND ITS INTEGRATED MANAGEMENT

VIDYA PALAKI

2015

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ABSTRACT

Maize (*Zea mays* L.) is an important cereal crop of the world. Among the many diseases affecting maize, leaf spot caused by *Curvularia lunata* (Wakk.) Boedijn is becoming a major constraint in the cultivation of maize in Karnataka. In India the disease has been reported from all the maize growing areas. Therefore, the present investigation was carried out with different objectives aiming at integrated management of the disease.

Roving survey was carried out during *kharif* 2014 in different taluks of Belagavi, Vijayapur and Bagalkot districts indicated varying intensities of the disease. The disease severity was higher in Gokak taluk (9.83 %) followed by Saundatti (8.97 %). Maximum disease severity was noticed in Arabhavi village (10.75 %) followed by Yaragatti village (10.03 %) of Gokak taluk of Belagavi district.

Studies on loss assessment in 15 maize genotypes due to *Curvularia* leaf spot (CLS) indicated that irrespective of the fungicidal spray higher grain yield recorded was in Mograon (80.32 q ha⁻¹) and the highest 100 grain weight was recorded (40.75 g) in the genotype NK 6240. Least grain yield (34.07 q ha⁻¹) and 100 grain weight (33.00 g) were recorded in Arjun.

Under *in vitro* studies irrespective of the concentrations, hexaconazole and carbendazim + mancozeb among fungicides, wanis among botanicals recorded maximum inhibition of mycelial growth and panchagavya among ITKs recorded cent per cent inhibition of spore germination. In Integrated Disease Management, the spray schedule hexaconazole @ 0.1 per cent- hexaconazole @ 0.1 per cent recorded the least CLS severity (42.35%), higher grain yield (79.58 q ha⁻¹) with higher benefit cost ratio (1: 3.81) followed by the spray schedule hexaconazole @ 0.1 per cent - wanis @ 0.5 per cent. Among 55 maize genotypes screened against CLS, one was found moderately resistant (CI 4), remaining genotypes showed susceptible to highly susceptible reaction.