

STUDIES ON POTATO WILT CAUSED BY *Sclerotium rolfsii* Sacc

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I. INTRODUCTION

Potato belongs to the family solanaceae and the genus solanum. The tuber bearing species have been identified as *Hypeorbasarthrum* under section *Tuberorium* (now called petota) of sub genus potato. The basic number of chromosomes of the genus *Solanum* is $X = 12$.

The potato belongs to the highland tropics of Andean mountains of Bolivia and Peru in South America, where, it has been under cultivation for over 6000 years and is believed to be introduced to India by Portugues during 17th Century (Pushkarnath, 1976).

The potato is one of the most important staple food crop, ranking fourth and fifth place in production and area in the world, respectively. The mineral production in case of potato is 3.70 times more than wheat and 11 times more than rice. Potato produces more carbohydrates, fiber and vitamins per unit area and time than the other major food crops. Potato is a low energy food, 200 g of boiled potatoes provide about 138 Kcal of energy (Shekhawat and Dahiya, 2000). It is rich in potassium and phosphorus (Shekhawat *et al.*, 1992). Tubers contain at least 12 essential vitamins and is a good source of vitamin 'C' containing about 14-25 mg/10 g of fresh weight of tuber (Thornton and Sieczka, 1980).

In the world, potato is grown in an area of 18.08 m. ha. with the production of 308.19 mt. and productivity of 16.02 tonn./ha (Singhal, 2003). India ranks fifth in area and production in the world, occupying an area of 11.00 per cent under potato. Potato crop occupies 0.60 per cent of total cropped area in the country, yet it contributes upto 1.80 per cent of total value of the agriculture output. In India, potato is cultivated in an area of 13.8 m ha with a production of 26.0 m t with a average yield of 18.84 t/ha in 2001 but projections made for the year 2020 to a tune of about 49 m tonnes of potato from two m ha with an average yield of 24.50 t/ha (Singhal, 2003). Productivity is quite low when compared to the developed countries (Netherland 45.00 t/ha, United Kingdom 41.30 t/ha, United States 37.40 t/ha) but, still higher than the world average. The per capita availability of potatoes in India is only 20 kg per year which is almost one third of the world average.

In India, potato is cultivated in almost all the states under diverse agro-climatic conditions. Nearly 82 per cent of the potatoes are grown in the plains during short winter days, about 10 per cent in hills under long day conditions during summer and rest of eight per cent in the plateaus region in the South Eastern and peninsular India as a rainfed crop during *Kharif* season.

Karnataka is one of the most important potato growing states in peninsular India, which has only 2.54 per cent of the total area under potato in the country. In Karnataka, potato was cultivated in on area of 39,156 ha with a production of 4.73 lakh tonnes and productivity of 12.72 t/ha during 2001 (Singhal, 2003). Potato is one of the main cash crops in six of its twenty districts. The state agro-ecology favours its cultivation during two seasons a year. *Rabi* (winter season) cultivation is popular in Kolar and Bangalore districts covering an area 8,000-12,000 hectares. *Kharif* (Rainy season) cultivation in Hassan, Chikmangalure, Dharwad and Belgaum districts. In an area of 36,000 ha potato produced in *Kharif* account for the major propotion (70%) of potato produced in Karnataka (Khatana *et al.*, 1997).

Commercially potato is propagated through tubers. Many disease causing agents *viz.*, viruses, fungus, bacteria, nematodes, viroids and phytoplasmas are reported on potato. Among the fungal diseases, wilt of potato caused by *Sclerotium rolfsii* Sacc. has attained the economic importance. In recent years this disease is increasing and causing huge losses in potato (Paul Kurana, 1998).

Webber (1943) reported about one per cent loss of tubers due to Sclerotium wilt when harvested in late May. Dutt *et al.* (1971) observed *S. rolfsii* disease in Rajgurunagar (Pune). Bisht (1982) reported the loss in yield with this disease has been upto 33 per cent in potato. Somani and Chauhan (1996) observed the overall average prevalence of *Sclerotium* rot (*S. rolfsii*) was five per cent during the three seasons. Incidence ranged from traces to two per cent and average was 1.20 per cent.

Jyotsana (1996) reported that, commercial potato varieties cultivated in Punjab showed 6.30-10.80 per cent tuber rot caused by *S. rolfsii*.

In Karnataka, Gadewar *et al.* (1991) reported the incidence range of 0.12-5.02 per cent in *Kharif* and 0.0-0.35 per cent in *Rabi*. The highest incidence was observed in Hassan (5.02%) followed by Dharwad (2.06%).

Anahosur and Kulkarni (1997) conducted roving survey in northern Karnataka during 1997 rainy season to assess the wilt in Dharwad and Belgaum districts on potato crop at 4-6 weeks growth stage and tubers stored in field. The average wilt in Dharwad taluk was 4.60 per cent, Belgaum taluk was 5.30 per cent and Hubli taluk was 1.20 per cent. Maximum tuber infection was reported in Kollur (22-25%) followed by in Hongarki (15.00%) and in Garag (10.00%). And also they observed the white, radiating mycelium and brown to dark brown sclerotia on tubers.

Anahosur *et al.*, (1997) conducted roving survey in parts of Karnataka and reported the average loss of 1-40 per cent in Dharwad taluk, 5.30 per cent in Bestwad and 1.20 per cent in Hubli taluk due to plant death. They also observed tubers covered with mycelium and brown sclerotia.

Presently, greater emphasis should be placed on organic amendments and bioagents for control of soil borne pathogens in order to reduce the environmental hazards, to avoid the development of resistant strains and reduce the cost of cultivation. So, the current investigation was carried out with following objectives:

1. Survey of *Sclerotium* wilt in potato growing areas of Dharwad and Belgaum districts.
2. Isolation, identification, proving pathogenicity and study of symptomatology.
3. Screening of early and medium maturing cultures of potato against the disease.
4. Management of the disease by organic amendments, bioagents and chemicals.
5. Effect of root exudates of potato on bioagents.

II. REVIEW OF LITERATURE

Sclerotium rolfsii Sacc. causing wilt of potato is a well known polyphagous, ubiquitous and a non-target pathogen. It is one of the most destructive soil inhabiting pathogen reported so far. The disease results in an uneven crop stand, loss of plant population and subsequently yield.

Pathogen

S. rolfsii is a well known polyphagous pathogen. The fungus was first reported by Rolfs (1892) as a cause of tomato blight from Florida in U.S.A. Saccardo (1911) named the fungus as *S. rolfsii* sp. nov. His Latin description of the fungus was based on the material collected in Florida by Rolfs and submitted by Stevens. In India, Shaw and Ajrekar (1915) isolated an organism from rotted potatoes and identified as *Rhizoctonia destruens* Tassi. But, later studies revealed that, the fungus involved was *S. rolfsii* (Ramakrishnan, 1930).

Higgins (1927) worked in detail on physiology and parasitism of *S. rolfsii*. This was the first detailed and comprehensive study in U.S.A. His studies laid the foundation for many subsequent investigations and the beginning of the modern era of research on this fungus. Curzi (1931) studied the perfect stage of the fungus in pure culture and proposed the generic name as *Corticium*. In India, Mundkur (1934) successfully isolated the perfect stage of *S. rolfsii*.

Importance and distribution of the disease

Sclerotium wilt or rot is a disease of tropics and subtropics. It is common where high temperature exists during the rainy season. It is a serious disease on potatoes in certain areas. The pathogen *S. rolfsii*, cannot with stand low temperate for long time, hence, it is not important in temperature regions. In India, it has been reported from Bengal and Bombay (Shaw and Ajrekar, 1915), Tamil Nadu (McRae, 1917) and Western India (Ajrekar, 1924). Since, 1961 the disease is of annual occurrence at Rajgurunagar (Pune), especially during *Kharif* season and recorded less than one per cent in 1964 and three per cent in 1968. In a badly affected crop, more than 50 per cent plants showed *Sclerotium* rot. The disease was quite serious in Satara region with an average incidence of five per cent wilt and 1-3 per cent tuber infection during 1968. It was destructive in stores and upto one per cent tuber may rot every day (Khanna and Sharma, 1993).

Dutt *et al.* (1971) reported 5-40 per cent damage due to this disease with more damage in *Kharif* than in *Rabi* crop. The disease also reported from Punjab cold stores, Madhya Pradesh and Karnataka. It was minor in Punjab but causes heavy losses both in the field and stores in areas of Deccan plateau (Anon., 1987).

Kulkarni *et al.* (1995) reported the tuber rot or wilt of potato as major problem in rainy season of transitional belt of Karnataka. Sporadic incidence of fungal wilts caused by either *S. rolfsii* or *Verticillium* sp. was found in Karnataka, North Gujarat and Satpura plateau (Madhya Pradesh) (Paul Kurana *et al.*, 1996).

Somani and Chauhan (1996) observed the overall average prevalence of *Sclerotium* rot caused by *S. rolfsii* in Gwalior, Madhya Pradesh, during 1988-89, 1989-90 and 1990-1991.

Symptomatology

Bisht (1982) described the symptoms as the mycelium infected the potato plants at collar region causing wilt which ultimately dried the plants: white or brown sclerotia were developed at maturity in the root and collar region of the infected plants. Infection spread within few days either by irrigated water or farm implements used for cultural practices. Pathogen damaged either stem, root or tuber.

Khanna and Sharma (1993) described the *Sclerotium* rot of potato as, dark brown lesion appeared on the stem just below the soil surface followed by wilting of lower leaves and gradually the whole plant dried. Such wilted plants showed white cover of fungal threads girdling the basal part of the stem, which moved above and below to the stem and roots.

Sclerotia resembled mustard seed, developed on hyphae grown on infected plant parts and soil.

Kulkarni *et al.* (1995) reported that, the pathogen damaged either stem, root or tuber. Infected stem produced dark brown lesion at collar region causing wilt and ultimately plants get dried. Brownish sclerotia resembled mustard seed developed at later stages on the root and collar region of the infected plants. Afterwards, tuber get infected and rotten in the field.

Somani and Chauhan (1996) observed a thin white mycelial mat on the tuber surface in fresh harvest and at times thick mat with mustard seed like sclerotia were found. *S. rolfsii* infected plants had white to mustard coloured sclerotia and thin white mycelial mat on almost all the daughter tubers, if the plants were wilted after tuber formation. They observed wilt at early stage before tuberization and then white mycelial mat and sclerotia. In the heap, the rot was spread from diseased to healthy tubers.

Anahosur (2001) observed dark brown lesion on the stem just below the soil surface followed by drooping and wilting of infected leaves and gradually wilting of the whole plant. Such wilted plant showed whitish mycelial growth with sclerotial bodies resembling mustard seeds on collar region and roots.

The affected tubers showed small sunken yellow to tan coloured spots with brownish margin. The affected tissue was tough and became soft and watery due to secondary rot causing organisms. The white mycelium of the pathogen grew rapidly over the tuber surface in a fan shaped outline.

Pathogenicity studies

Difference in morphology and pathogenicity were reported as early as in 1923 by Edson and Shapovalov for the isolates of *S. rolfsii* from North Carolina and Arkansas. One of those two isolates was found to be more virulent in potato seed decay.

Sengupta and Das (1970) studied the cross inoculation of isolates of *S. rolfsii* from groundnut, wheat, potato, guava and bengal gram. They concluded that bengal gram was the most susceptible host. Although isolates were most virulent to their appropriate hosts the specialization was not demonstrated conclusively.

Datar and Bindu (1974) proved the pathogenicity of *S. rolfsii* on sunflower by soil inoculation method under glasshouse condition. The inoculum was prepared by growing the fungus on sterilized maize bran medium and mixed with the sterilized soil one week before sowing. Typical symptoms were produced within a week of inoculation which were identical to those produced in the field.

Mishra and Bais (1987) used 15 days old fungal culture grown on sand corn meal medium for proving pathogenicity of root rot of barley caused by *S. rolfsii*, by mixing upper 4-5 cm layer of soil with inoculum at the rate of one flask per pot.

Siddaramaiah and Chandrappa (1988) proved the pathogenicity of *S. rolfsii* on cardamon in pot culture studies by inoculating 25 days old sclerotial cultures which was grown on sand corn meal medium and observed the symptoms a week after inoculation.

Siddaramaiah (1988) confirmed the pathogenicity of *S. rolfsii* on *Desmodium uncimatum* Desv and *Cotonoris bainesii* Eckl and Zeyh, two important forage legumes of hill zone by similar procedure.

Kulkarni *et al.* (1994) while studying the most susceptible growth stage of groundnut to *S. rolfsii*, maximum mortality was recorded in 15 days old plants and the least mortality in 105 days old plants.

Survey

Singh *et al.* (1987) proposed that, the disease incidence varied with soil moisture and soil temperature while, a maximum of 72 per cent disease incidence was recorded at high relative humidity and moderate temperature in case of collar rot of pigeonpea incited by *S. rolfsii*.

Kulkarni *et al.* (1988) carried out a survey on the incidence of foot rot of wheat caused by *S. rolfsii* during Rabi 1987-88 in major wheat growing areas of north Karnataka both under

rained and irrigated conditions. They reported that in irrigated fields, the disease severity varied from low to medium, while, it was severe under rainfed conditions.

Palakshappa *et al.* (1988) surveyed the incidence of *S. rolfsii* on *Piper betle* Linn. in different areas of Karnataka state during 1984-85 and recorded 35 to 39 per cent disease incidence.

Guliya *et al.* (1991) carried out intensive survey on the incidence of *S. rolfsii* on sunflower in California and recorded nine per cent disease incidence.

Okoli *et al.* (1991) surveyed the incidence of basal stem rot and wilt of sunflower caused by *S. rolfsii* in the northern Guinea savannazone of Nigeria and revealed sporadic appearance of wilted and dried out plants with basal stem dry rot.

Sujatha (1991) carried out survey on the incidence of foot rot of ragi caused by *S. rolfsii* around Bangalore during 1988-89. Maximum disease incidence of 22 per cent was recorded on this crop.

Anahosur and Kulkarni (1997), conducted a roving survey in 1997 on wilt of potato caused by *Sclerotium rolfsii* and reported that, maximum wilt incidence was recorded in Puddalakatti (40%), followed by Tadakod (20%) in Dharwad and Bastewad (40%) in Belgaum.

Anahosur and Kulkarni (1997), conducted a survey of tuber infection under storage in the field. Maximum infection was recorded in Kollur (22-25%), followed by Hangarki (15%).

Screening of early and medium maturing cultures against *Sclerotium* wilt

Anahosur (2001), screened 16 genotypes of potato against *Sclerotium rolfsii* in pot culture technique. Study revealed that, five varieties were found resistant to *Sclerotium* wilt on the contrary two varieties were found highly susceptible. Variety Kufri Chandramukhi and JH-222 showed susceptible reaction at one per cent inoculum level, while it was completely killed at two and four per cent.

Anahosur (2001) screened potato varieties against *Sclerotium rolfsii* in sickplot. Study revealed that, non of the varieties showed immune or highly resistance reaction against the *Sclerotium* wilt. Among twenty varieties nine varieties were highly susceptible only two are moderately resistant to wilt. Variety 66-P-127 showed thirty-three per cent wilting, JX-254 showed 47 per cent wilting, Kufri sutlez showed 60 per cent wilting, MP/90-542 recorded 67 per cent wilting and highly susceptible reaction was recorded in 85-P-718 and JX-54. Among the genotypes screened, 11 genotype showed moderate resistant reaction and genotype viz. CP-49 and CP-1503 showed highly susceptible reaction.

Inoculum level and infection

Garret (1956) defined inoculum potential as the energy for growth of a parasite available for infection of a host, at the surface of the organ to be infected. For development of root rot diseases, certain number of fungal propagules should always survive in soil.

Kilpatrick and Merkle (1967) reported the effect of different levels of *S. rolfsii* inoculum on foot rot of wheat and found that, 0.5 and 1.0 per cent inoculum was superior to 3, 5 and 10 per cent. However, considerable amount of infection was recorded in two per cent inoculum and 100 per cent disease in six per cent and above inoculum level (Nargund, 1981).

Palakshappa *et al.* (1987) observed considerable foot rot infection, when betelvine were inoculated with two and three per cent inoculum. And they recorded 100 per cent infection at four per cent and above inoculum levels.

Harlapur (1988) reported that, two per cent inoculum was essential for infection. But, maximum infection (100%) was noticed in inoculum level of more than four per cent in foot rot disease of wheat.

Uma Singh and Thapliyal (1998) reported inoculum density levels of 2.5 to 10 g/kg soil significantly increased the emergence rot which was ranged from 36.70 to 90 per cent in seed and seedling rot of soybean caused by *S. rolfsii*.

Management by organic amendments

The use of organic and inorganic amendments have been suggested by several workers to control soil born pathogens.

King and Loomis (1926) reported that, heavy application of organic matter to the soil results in the effective control of *Phymatotrichum* root rot of cotton.

Fellows (1929) studied field control of take all disease of wheat by application of organic amendments viz. chicken and horse manure, green alfalfa, boiled oats, barley kernels and potato flour.

Chaudhary (1946) reported that, application of manure reduced the death of betelvine plants due to infection of *Sclerotium rolfsii*. Among the organic amendments tested the mustard oil cake was found to be effective.

Mathur and Sinha (1970) reported reduced infection due to *S. rolfsii* in case of root rot of guar (*Cymopsis psoraloides* D.C.) and wilt of gram (*Cicer arietinum* L.) by the application of F.Y.M.

Singh *et al.* (1972) showed that, mustard and groundnut cakes were more effective in reducing the incidence of black scurf of potato caused by *Rhizoctonia solani* Kuhn. followed by saw dust and margosa cake.

Lingaraju (1977) reported that, groundnut oil cake was most effective followed by F.Y.M. in suppressing the saprophytic activity of *S. rolfsii*. Similarly, plant residues viz., paddy hull and wheat bran were also equally effective in keeping the saprophytic activity of the fungus at a low level.

Nargund *et al.* (1984) reported that, the safflower oil cake and groundnut oil cake were more effective in reducing the mortality of wheat seedling due to *S. rolfsii* and thus increased the yield followed by F.Y.M., paddy hull and wheat bran. They further reported that, these amendments were found to be effective, as the period after incorporation of amendments and sowing of the crop.

Nishatkhalis and Manoharachary (1985) observed that, *Fusarium solani* spp. and *Wolleu* disappeared from soils, amended with safflower, groundnut and neem cake within few days.

Punja (1985) reported that, the addition of organic amendments such as compost, oats or corn straw to soil limited the disease caused by *S. rolfsii*, possibly due to release of toxic ammonia or increased in the level of resident antagonistic soil micro organisms.

Palakshappa (1986) found that, the maximum suppression of the saprophytic activity of *S. rolfsii* causing foot rot of betelvine by groundnut and safflower oil cake, and F.Y.M., paddy hulls and wheat bran were less effective.

Rajan *et al.* (1991) reported that, the disease incidence was reduced to 4.90 per cent by the application of neem cake in case of root rot of fenugreek, caused by *Rhizoctonia solani* Khun.

Ram and Tewari (1994) reported that, soil application of green leaves of *Adhatoda vasica*, *Acgla marmelos*, *Anisomeles ovata*, *Azadirachta indica*, *Cymtopogan flexuosus*, rhizomes of *Curcuma amada* and resin of *Ferula fostida* at two and five per cent concentration reduced both pre and post-emergence collar rot of chickpea caused by *Sclerotium rolfsii*. Five per cent *F. fostida* resin applied 48 hours before sowing of seeds in artificially inoculated soil proved nearly 100 per cent protection.

Goudar *et al.* (1998), conducted pot experiment to determine the effect of organic amendments on the incidence of pigeonpea wilt caused by *Fusarium udum*. Neem cake and compost were effective in reducing wilt incidence and improving seed germination. The highest per cent survival of plants was recorded when neem cake was amended to the soil, followed by compost, FYM and groundnut oil cake. There was no adverse effect on seed germination in soil amended with organic amendments.

Chattopadhyay *et al.* (1999) reported that, mustard cake amendment appeared to be the most effective for the reduction of the population of all three soil borne fungal pathogens (*Macrophomina phaseolina*, *Fusarium oxysporum* and *Sclerotium rolfsii*) of chickpea, followed by green manure and FYM.

Padmodaya and Reddy (1999) studied six organic amendments namely, neem cake, pongamia cake, pongamia fresh and dry leaves, eucalyptus leaves and farm yard manure (FYM) against seedling disease in tomato caused by *Fusarium oxysporum* f. sp. *lycopersici*. Among these organic amendments FYM was found significantly superior to all others with 66 per cent mean healthy seedlings followed by neem cake (61%) and pongamia fresh leaves (61%).

Gurjar *et al.* (2003) reported that, collar rot of chilli caused by *Sclerotium rolfsii* and studied the effect of organic amendments like FYM, vermicompost, cotton oil, mustard oil, castor oil, neem oil and groundnut oil against the disease. All amendments were found significantly superior compared to control. Neem cake was found most effective with the least disease incidence of 18.50 per cent.

Karunanithi *et al.* (2003) conducted a field experiment to manage the basal stem rot of (Ganoderma) of coconut. *Pungamia glabra* recorded the least disease index of 21.30. This was followed by *Azadirachta indica* and *Prosopis juliflora* which recorded 23.60 and 28 per cent disease index compared to 47.50 per cent in control.

Padmodaya (2003) reported that, *Fusarium* wilt of tomato was reduced by application of neem cake, which was significantly superior with PDI of 48.76 per cent followed by FYM (50.97%), while, in control PDI was 80.50 per cent.

Management by bioagents

Micro-organisms that can grow in the rhizosphere are ideal for use of biocontrol agents, since, the rhizosphere provides the front line defense for roots against the pathogens. Pathogens encounter the antagonism from rhizosphere micro-organisms before and during primary infection and also during secondary spread on the root.

Burr *et al.* (1978) observed that, strains of *Pseudomonas fluorescens* and *P. putida*, applied to seed pieces, improved the growth of potato. Root colonization by the introduced bacteria is essential for biocontrol of root pathogens and that increasing population of an introduced bacterium on the root should enhance disease control (Suslow, 1982).

Application of *T. harzianum* to the root zone of tomatoes controlled *S. rolfsii* infection in naturally infested soil and further on transplanting the treated plants showed reduced disease incidence to the tune of 93 per cent (Elad *et al.*, 1980).

Saraswathi and Pal (1986) reported that, the application of *T. viride* or *T. harzianum* cultures or filtrates to the pots or under field conditions effectively controlled the collar rot of pigeonpea.

Wokocha *et al.* (1986) observed 90 per cent of groundnut plants protected from the infection of *S. rolfsii*, when inoculated with *P. fluorescens* (10^8 cfu/ml).

Harlapur (1988) found that, seed treatment and soil drenching with antagonistic cultures reduced the mortality of wheat seedlings to a considerable extent by suppressing the *S. rolfsii*. However, soil drenching was more effective compared to seed treatment. Among the antagonistic organisms tested, *T. harzianum*, *T. viride*, *B. subtilis* and *Streptomyces* sp. were more effective both as seed and soil treatment.

Bacteria have been proved to be potential for biocontrol, occur in many genera and were found effective even under field conditions. A comprehensive review on the use of rhizosphere bacteria as biocontrol agents against soil borne diseases has been made by Weller (1988).

Papavizas and Lewis (1989) reported that, the *T. harzianum* and *G. virens* reduced the damping-off and blight of Snapbean caused by *S. rolfsii* under green house conditions. Seed treatment with *G. virens* (10^9 spores/ml) reduced the stem rot of groundnut caused by *S. rolfsii* (Sreenivasa Prasad and Manibhusan Rao, 1993).

Kulkarni and Kulkarni (1994) and Virupaksha Prabhu *et al.* (1997) showed that, seed and soil treatment with *T. viride* and *T. harzianum* were the most effective in reducing the

mortality percentage of groundnut and cotton seedlings. *T. harzianum* helped to increase the seedling emergence of groundnut (Jagadeesh and Geeta, 1994).

Anahosur *et al.* (1998) reported effective role of bioagents on *Sclerotium* wilt of potato. *T. harzianum* and *T. viride* gave good and *G. virens* and *P. fluorescens* gave moderate per cent germination and produced more yield compared to control, when tubers treated with one per cent solution of antagonists.

Rajendra *et al.* (1998) reported that, seed bacterization of groundnut with *P. fluorescens* significantly improved the groundnut seed germination, nodulation, dry matter production and pod yield, besides protecting the plants from infection due to *S. rolfsii*.

Sheela *et al.* (1998) observed that, collar rot disease incidence of groundnut was the lowest (23.33%) in peat soil inoculated with *P. fluorescens* as against the highest (85%) incidence in control.

Anahosur (1999) and Anahosur *et al.* (1999) reported their work on the incidence of *Sclerotium* wilt in some parts of northern Karnataka and the affect of different bioagents in disease management.

Thiribhuvanamala *et al.* (1999) reported that, soil amendment with *T. harzianum* resulted the better plant stand upto 80 per cent at 60 days after sowing followed by *T. viride* and *P. fluorescens* in pot culture studies.

Desai and Schlosser (1999) reported that, among forty-four isolates of *Trichoderma* belonging to eight species, eight isolates of *T. harzianum*, three isolates of *T. hamatum* and *T. koningii* could kill the inoculated sclerotia, by penetrating, establishing and sporulating inside the sclerotial bodies.

Biswas and Sen (2000) reported that stem rot of groundnut caused by *S. rolfsii* was significantly reduced by *T. harzianum* when delivered as seed dressing or soil application in the pot trials. Per cent disease reduction through seed dressing was 33 to 50 per cent and through direct soil application was 72 to 83 per cent over control.

Bari *et al.* (2000) reported antagonistic activity of *T. harzianum* against foot rot of barley caused by *S. rolfsii*. *T. harzianum* significantly reduced the disease incidence and enhanced the seed germination and plant growth.

Anahosur (2001) reported that, *T. harzianum* recorded the least wilt (10%) followed by *T. viride* (14%) and were the best treatments in reducing the disease, of potato wilt caused by *Sclerotium rolfsii*.

Vanitha and Suresh (2002) reported that, the lowest collar rot of brinjal (9.44%) caused by *Sclerotium rolfsii* in *T. harzianum* seed treatment + soil application of adathoda leaf powder and FYM treated plots as compared to control (39.30%).

Alonso *et al.* (2002) studied the bicontrol activity of *Trichoderma harzianum* strain A34 against *Sclerotium rolfsii* under greenhouse conditions and reported that efficacy of the biocontrol agent was confirmed by the absence of disease symptoms in protected tomato seedlings cultivated upto 30 days after germination.

Ram and Bhanushally (2003) reported that, collar rot of groundnut caused by *Aspergillus niger* incidence was significantly reduced (7.77%) as compared to check (25.81%) when seeds were treated with *Trichoderma harzianum* (10 g kg⁻¹ seed) in combination with soil application of *T. harzianum* (@ 4 kg ha⁻¹).

Narasimha Rao *et al.* (2004) reported that, among the bioagents *T. harzianum* showed the lowest disease incidence of 10.20 per cent followed by *T. viride* 12.00 per cent which differed significantly.

Fateh Singh *et al.* (2004) reported that, *T. viride* significantly reduced seedling mortality in tomato caused by *Fusarium oxysporum* f. sp. *lycopersici*, followed by *G. virens*, *T. harzianum* which were on par with each other.

Management by chemicals

The chemical control of *S. rolfsii* on a commercial basis was economical with most crops until the chlorothitrobenzenes were developed. Application of quintozone at the rate of

15-20 kg per ha has been found to be effective in reducing the activity of *S. rolfsii* (Gould, 1954; Mukhopadhyay and Thakur, 1971 and Agnihotri *et al.*, 1975).

Several workers reported the inhibitory effect of PCNB on *S. rolfsii* while working with root rot and collar rots of various crop plants (Harrison, 1961; Abeygunawardhana and Wood, 1975; Mishra and Chand, 1970; Anilkumar *et al.*, 1976; Kulkarni, 1980; Nargund, 1981 and Sharma and Verma, 1985).

Several workers found that benodanil (Jobebezaniilide) was highly effective in inhibiting *S. rolfsii* mycelial growth (Maiti and Choudhary, 1975; Pan and Sen, 1977; Siddaramaiah *et al.*, 1979 and Kulkarni *et al.*, 1986).

However, Maiti and Choudhary (1975) reported the effectiveness of carboxin in inhibiting *S. rolfsii* under laboratory conditions. Pan and Sen (1977) reported the effectiveness of campogrom-M (50% 2,5-dimethylfuron-3-carbamoyl acid anilide + zinc manganese ethylene bisdithiocarbamate) in significantly inhibiting sclerotial germination and mycelial growth of the *S. rolfsii*. While, Vyas and Joshi (1977) screened several fungicidal compounds (including both systemic and non-systemic) against collar rot of wheat caused by *S. rolfsii* and recorded that, Mertect and Triforine completely inhibited the growth of the fungus at 200 and 100 ppm respectively.

Effectiveness of plantavax and vitavax was recorded in inhibiting the vegetative growth of *S. rolfsii* was reported by several workers (Vyas and Joshi, 1977; Siddaramaiah *et al.* 1979; Nargund, 1981; Palakshappa, 1986 and Kulkarni *et al.*, 1986).

Siddaramaiah *et al.* (1979) and Kakade and Khune (1989) reported the effectiveness of Calixin in completely inhibiting *S. rolfsii* *in vitro*. However, they also found that, bayleton and panovam inhibiting the germination of sclerotia at 100 ppm.

Bavistin was found effective against growth of *S. rolfsii* (Siddaramaiah *et al.*, 1979; Kulkarni *et al.*, 1986 and Virupaksha Prabhu, 1994).

Vrany *et al.*, (1984) and Virupaksha Prabhu (1994) stated that, daconil 2785-W-75 and chlorothalonil were highly effective against *S. rolfsii*. Further, Harlapur and Srikant Kulkarni (1992) and Virupaksha Prabhu *et al.* (1997) noticed complete inhibition of growth of *S. rolfsii* with Dithane M-45 and agallol.

Kakade and Khune (1989) studied the effect of some fungicides against several phytopathogenic fungi and found that, delsan (30EC) was highly inhibitive at 0.25 and 0.35 per cent.

Soil drenching with sodium dehydroacetate or formalin gave excellent control of *S. rolfsii* (Abeygunawardhana and Wood, 1975).

Captan was reported as effective soil drenching fungicide by several workers. Aycock (1959) found that soil application of captan at the rate of 87 lb was effective against *S. rolfsii*. Agrawal and Singh (1969) found that, captan reduced post emergence mortality due to foot rot of wheat.

However, Agrawal and Singh (1969) tested several soil drenching fungicides against foot rot of wheat caused by *S. rolfsii* and found that, rhizoctol was most effective and could control post emergence mortality completely. This was followed by arason and bisdithane.

Pal and Choudhary (1983) reported the efficacy of vitavax as soil drenching fungicide against *S. rolfsii* in reducing the sunhemp seedling mortality. They also reported that, bayleton and sicoral were highly effective as soil drenching whereas baycor, breston and thiram were moderately effective at two inches layer of the soil column.

Similarly, brassicol was found effective against *S. rolfsii* (Pal and Choudhary, 1983 and Sharma *et al.*, 1990). However, Sharma *et al.* (1990) reported the efficacy of several other chemicals as soil drenching fungicides against *S. rolfsii* isolated from sugar beet. Calixin (Tridemorph) and demosan (Chloroneb) gave most effective control of the disease.

Harlapur and Srikant Kulkarni (1992) observed that, vitavax, bayleton and bayton were highly effective at all concentrations tested against foot rot of wheat caused by *S. rolfsii* under glasshouse conditions and reported that vitavax was found to be the best in reducing the pre-emergence and post emergence mortality of wheat seedlings.

All four ergosterol biosynthesis inhibiting triazole fungicides (tebuconazole, cyproconazole, Propiconazole and difencarazole) tested were found effective in reducing stem colonization by *S. rolfsii* to the extent of 64.20 per cent (Adiver and Anahosur, 1995).

Vanitha and Suresh (2002) reported that, seed treatment with carbendazim recorded significantly the lowest incidence (10.83%) of collar rot of brinjal caused by *S. rolfsii* compared to control (39.30%).

Viswakarma and Basu (1982) reported that, vitavax (Carboxin) seed treatment was the most effective against the root disease of *Cicer arcticum* caused by *S. rolfsii*.

Tiwari and Ashok (2004) reported that, fungicides like Carboxin, Epoxiconazole, Hexaconazole, Propiconazole and Triadimefon which were found highly effective against *Rhizoctonia solani* and *S. rolfsii*, and can be formulated as seed dresser either with thiram or mancozeb to control both collar rot and root rot as well as seed mycoflora effectively.

Root exudates

Root exudation is a phenomenon common to all higher plants which directly or indirectly effects the root attacking pathogens. Resistance or susceptibility to a soil borne pathogens is determined by nature of root exudates. Root exudates are defined as those substances which are released into the surrounding medium by healthy and intact plant roots. These substances may be inhibitory or stimulatory to the root infecting pathogens.

As there are no reviews on effect of root exudates on *T. harzianum* and *T. viride* which are being used as bioagents, the reviews on other fungus was mentioned.

One of the first investigation on the role of cyanogenic β -glucoside, linamarin and its aglycone HCN in resistance of flax to *Fusarium oxysporum* f. sp. *lini* (Bolley) Snyder and Hansen, was reported by Reynolds (1931). Timonin (1944) found that, when a wilt resistant and a wilt susceptible varieties of flax were used, the population of several species of pathogenic fungi including *F. o. f. sp. lini*, was depressed more in the rhizosphere of the resistant variety. The difference was due to the exudation of greater amounts of HCN in the rhizosphere of resistant plants.

Eaton and Rigler (1946) reported that, resistance of cotton and immunity of corn to root rot caused by *Phymatotrichum omnivorum* (Shear) Dugger might be related to the population of fluorescent pseudomonads. The composition of the rhizosphere microflora for cotton and corn was influenced by the nature of root exudates. The specificity of pea root exudates towards pathogenic fungi was demonstrated by Buxton (1957) and found that, the exudates from cultivars resistant to *Fusarium oxysporum* f. sp. *pisi* (Linf.) Snyder and Hansen depressed the germination of conidia and mycelial growth of the fungus.

Tichelaar (1961) reported that, sclerotia of *Sclerotium cepivarum* Berk were depressed in soil when gladiolus was planted. But, laboratory studies demonstrated that, root exudates from gladiolus stimulated the germination of sclerotia.

In another study, on the relation between HCN concentration in roots of sorghum to the population of rhizosphere microflora by Rangaswami and Balasubramanian (1963) showed that, the bacterial population was reduced in the rhizosphere of some varieties with a high HCN content in roots and stimulated in the rhizosphere of others.

Rangaswami and Vidhyasekaran (1963) reported that, a *Streptomyces* sp. produced an antibiotic in the rhizosphere of corn which inhibited the growth of *Helminthosporium sativum* pammel, King and Bakke.

Cooper (1956) observed nine per cent stem rot incidence of peanut, when there was continuous cropping of groundnut. But, five and three per cent incidence were noticed, when peanut was rotated with soybean and corn, respectively. In groundnut, grown after onion, *Sclerotium* root rot incidence was reduced by 62 per cent and pod yield increased by 15-52 per cent in field conditions (Zeidan *et al.*, 1986).

Pearson *et al.* (1987) noticed that, soil population of *M. phaseolina* was lowered by following maize after maize cropping sequence than soybean after soybean cropping sequence. Lipps (1988) reported low stalk rot incidence of corn, when maize was rotated with soybean. The lowest sclerotial number was recorded in fields, when groundnut followed by maize or sorghum was the last crop before sampling (Wokocha, 1988).

The concentration of phenolic compounds were higher in root exudates of cowpea when collected from 30 days after germination than 15 days after germination. Mycelial growth of *R. solani* was greater in exudates from FOS-1 (Susceptible cultivar) than CS-80 (Moderately susceptible cultivar) and increased with increasing concentration of the exudates from 25 to 100 per cent (Satish Mehta *et al.*, 1992).

Brennemon *et al.* (1995) reported that, reduction in stem rot incidence (23%) was recorded when peanut rotated with bahia grass against peanut monocropping (44%).

Stevenson *et al.* (1995) reported that, spore germination of race of *Fusarium oxysporum* f. sp. *cicer* (Podwick) Snyder and Hansen was significantly inhibited by root exudates of the wilt resistant chickpea cultivars CPS 1 and WM 35 compared to untreated spores and spores treated with root exudates from susceptible cultivars.

Hillocks *et al.* (1997) reported that, exudates solutions from sorghum were inhibitory to chlamydospore germination of *F. oxysporum* f. sp. *udam* (But.) Snyder and Hansen whereas exudates solutions from cotton and pigeonpea were stimulatory to germination of chlamydospores of their respective pathogens.

Anahosur *et al.* (1998) reported that, the root exudates from four varieties of sorghum prevented the sclerotial germination and groundnut root exudates supported the sclerotial germination under *in vitro*.

Sinha and Pandey (1999) reported that, roots of tomato and brinjal secreted substances favourable for germination of sclerotia of *Ozonium texanum* var. *parasiticum* (Meal and Webster) Thirum. Whereas, secretion from roots of chilli inhibited sclerotial germination, due to presence of some toxic substances and its toxic influence decreased when dilutions were made.

Narasimha Rao (2000) reported that, among the root exudates tested, sorghum root exudates were more effective in inhibiting the germination of sclerotia and mycelial growth followed by maize and bajra.

Narasimha Rao (2000) reported that, toxic substances present in root exudates were higher, when the root exudates collected 20 days after sowing than 10 days after sowing, which inhibited both sclerotial germination and also mycelial growth.

Anahosur (2001) reported that, sorghum varieties completely prevented the sclerotial germination, whereas, maximum sclerotial germination was recorded in groundnut and bengalgram (90 per cent and 93.33 per cent respectively). Similarly 23.33 per cent sclerotial germination was observed in maize root exudates, while, it was 26.66 per cent germination in sunflower. Root exudates of redgram allowed 33.33 per cent sclerotial germination whereas it was 43.30 per cent in greengram.

III. MATERIAL AND METHODS

The various aspects of current investigation on wilt of potato were undertaken in the Department of Plant Pathology, University of Agricultural Sciences, Dharwad.

General laboratory procedures

Glassware and cleaning

For all the laboratory experimental studies corning and borosil glasswares were used. Before using the glassware were kept for 24 hours in the cleaning solution containing 60 g of potassium dichromate and 60 ml of concentrated sulfuric acid in 1000 ml of water and then washed with washing powder followed by tap water and finally rinsed with distilled water.

Sterilization

All the glasswares were sterilized in an autoclave at 1.1 kg/cm² pressure for 20 minutes and then kept in hot air oven at 160°C for two hours. Both solid and liquid media were sterilized at 1.1 kg/cm² pressure for 15 minutes. Soil used for pot culture experiments was sterilized in an autoclave at 1.4 kg/cm² for two hours.

Preparation of medium

Potato dextrose agar (PDA)

In all the experimental studies, the standard potato dextrose agar medium was used.

The composition of potato dextrose agar medium was as follows.

Peeled potato	200 g
Dextrose	20 g
Agar-agar	20 g
Distilled water	1000 ml (to make up the volume)

Two hundred grams of cleaned, washed and peeled potato tubers were chopped into pieces. Later these pieces were boiled in distilled water and the extract was collected by filtering through muslin cloth. Dextrose and agar-agar 20 g of each were dissolved in the potato extract and the volume was made upto 1000 ml by adding distilled water. Known quantity of medium was dispensed into number of conical flasks and plugged with non-absorbent cotton and finally wrapped with brown paper. The flasks containing dispensed medium was sterilized at 121.60°C temperature for 15 min.

Kings B medium

For maintenance of *P. fluorescens* fresh culture, the Kings B medium was used. The composition of Kings B medium was as follows (Sands and Rovira, 1970).

Peptone	20 g
Agar agar	12 g
Glycerol	8 ml
K ₂ HPO ₄	1.50 g
MgSO ₄ ·7H ₂ O	1.50 g
PH	7.0
Distilled water	1000 ml (To make up the volume)

All the components excluding the agar were mixed together as a dry powder before distilled water was added. After adjustment of pH to 7.0 the agar was added and medium was autoclaved and cooled to 45°C and then 10 ml of freshly prepared antibiotic mixture was added per litre of medium. Cooling was essential to maintain the activity of the antibiotics.

The disease survey

Survey on incidence of potato wilt caused by *S. rolfsii* was carried out during *Kharif* 2004, in Belgaum and Dharwad districts. Five spots from each field and 100 plants from each spot were selected randomly. The total number of plants present and number of plants showing wilting symptoms due to sclerotium in each spots were counted and recorded. The per cent disease incidence was calculated by using following formula.

$$\text{Per cent disease incidence} = \frac{\text{Number of wilted plants in a spot}}{\text{Total number of plants present in the spot}} \times 100$$

Collection of diseased samples and isolation of the pathogen

Samples of potato plants showing the typical symptoms of *Sclerotium* wilt were collected from experimental plot at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The infected portion of plant parts were used for isolation. The isolation of fungus was made by following standard tissue isolation procedure.

The infected tissue was cut into small bits and washed in running water. These bits were surface sterilized with 1:1000 mercuric chloride solution for one minute. After that, the bits were washed thoroughly with sterile distilled water three times to remove the traces of mercuric chloride if any and then aseptically transferred to petriplates containing the sterilized PDA medium. Then these plates were incubated at $27 \pm 1^{\circ}\text{C}$ for three days. The fungal growth on fourth day, which arose through the infected tissue was cut by inoculation loop and transferred aseptically to the PDA slants.

Maintenance of the culture

The fungus was sub-cultured on the PDA slants and allowed to grow at $27 \pm 1^{\circ}\text{C}$ temperature. The culture so obtained was stored in refrigerator at 5°C for further studies and was sub cultured periodically.

Multiplication of mass inoculum

In order to get maximum sclerotial bodies for mass multiplication of inoculum sand-corn meal medium was used. The proportion of sand-corn meal medium was 95:5 as described by Abeygunawardhana and Wood (1975). Two hundred grams of sand corn meal mixture was taken in 500 ml of conical flasks, to which a sufficient quantity (moisture holding capacity) of distilled water was added and sterilized at 1.4 kg/cm^2 pressure for 20 minutes. The pure culture of *S. rolfsii* was inoculated to these flasks under aseptic conditions and incubated at $27 \pm 1^{\circ}\text{C}$ for 30 days. These flasks were shaken periodically to get uniform growth. The giant culture so obtained was used for further studies.

Proving the pathogenicity

Sterilized soil was taken in earthen pots of size 45 x 30 cm. Thirty days old culture grown on sand-corn meal medium was mixed thoroughly at four per cent w/w basis, applied on top 3 inch of the soil. Then apparently healthy surface sterilized potato tubers were planted in pots filled with culture as described above. Tubers planted in pots without inoculum served as control. Soil moisture was maintained at 25 per cent moisture holding capacity of soil by adding sterilized water on weight basis throughout the period. After 20 days of inoculation, the plants showing the typical wilting symptoms were observed. Reisolation was made from such affected portion of the plant tissue and compared with that of original isolate.

Identification of pathogen

For identification of the pathogen, the fungus was grown on PDA slants. Six days after incubation photographs of white radiating mycelial mat were taken. After the development of Sclerotial bodies at the peripheri of the plates the diameter of sclerotial body was measured with the help of vernier callipers.

Screening of early and medium maturing cultures of potato against *Sclerotium* wilt

In order to locate resistance against *S. rolfisii*, potato early and medium maturing cultures were screened in *Sclerotium* sick plot and the observations were made based on per cent disease incidence at crop maturity stage.

Grouping was made based on their per cent disease incidence.

Sl. No.	Per cent disease	Category
1	0 (no disease)	Immune
2	1-5 per cent	Resistant
3	6-10 per cent	Moderately resistant
4	11-15 per cent	Moderately susceptible
5	16-25 per cent	Susceptible
6	>26 per cent	Highly susceptible

Cultures used for screening are

Early maturing	Medium maturing
1. K. Ashoka	1. MS/94/899
2. J/93-4	2. K. Anand
3. J/92-13	3. MS/95-117
4. J/92-167	4. MS/92-1090
5. K. Jawahar	5. MS/93
6. J/93-8	6. K. Pukraj
7. J/93-139	7. MS/95-1039
8. J/94-90	8. MS/94-1118
9. J/93-58	9. JW-160
10. J/92-159	10. JX-576
11. J/92-164	

Management of the disease using organic amendments, bioagents and chemicals

A pot experiment was conducted during *Kharif* 2004 in glasshouse of University of Agricultural Sciences, Dharwad, Department of Plant Pathology, College of Agriculture, Dharwad.

This experiment was conducted to know the efficacy of different organic amendments, bioagents and chemicals (listed below) in controlling (managing) the *Sclerotium* wilt of potato. Sieved soil was filled in earthen pots and one month old culture of *S. rolfisii*, grown on sand corn meal was mixed at four per cent w/w basis to have sick soil in pots. Moisture was maintained at 25 per cent water holding capacity (M.H.C.).

Three different sets were maintained such that, first set for organic amendments, second set for bioagents and third set for chemicals. After one month organic amendments (listed below) were added to the first set and let it for two weeks at 25 per cent M.H.C. At the

time of planting in the first set (pots with organic amendment) tubers were planted without any treatment. In the second set tubers were treated with bioagents (listed below) and in third set tubers were treated with the chemicals (listed below) before planting. Here each treatment of first and third sets was replicated three times and second set was replicated four times and a control was maintained without any treatment.

Organic amendments

Among the organic amendments fresh leaves and cakes were used i.e.

Organic amendments

1. *Azadirachta indica* leaves (30 g/kg of soil)
2. *Parthenium hysteroforus* leaves (30 g/kg of soil)
3. *Pongamia glabra* leaves (30 g/kg of soil)
4. FYM (25 g/kg of soil)
5. Neem cake with oil (20 g/kg of soil)
6. Neem cake without oil (20 g/kg of soil)
7. Vermicompost (20 g/kg of soil)
8. Control

Bioagents

Bioagent viz., *Trichoderma* sp. were multiplied on potato dextrose broth and *Pseudomonas* sp. on nutrient broth by incubating at $27\pm 1^{\circ}\text{C}$ and shaking flasks for every alternate days. Later culture was blended and mixed with carrier material like Talk (sterilized) and treated to healthy tubers used for planting.

Bioagents

1. *Pseudomonas* sp. (10 g/lit of water)
2. *T. harzianum* (10 g/lit of water)
3. *T. virens* (10 g/lit of water)
4. *T. viride* (10 g/lit of water)
5. *T. koningii* (10 g/lit of water)
6. Control

Chemical

Tubers were treated with the chemicals (listed below) at the time of planting.

1. Carbandazim (0.1%)
2. Carboxin (0.05%)
3. Captan (0.2%)
4. Emisan (0.1%)
5. Hexaconazole (0.1%)
6. Metalaxyl M-Z (0.2%)
7. Propiconazole (0.1%)
8. Triademefon (0.1%)
9. Control

Effect of root exudates

The study was conducted in the laboratory to know the effect of root exudates of various crops (potato, sorghum and maize) on the spore germination of effective bioagents i.e., *T. harzianum* and *T. viride* which may provide some clues for using these crops in rotation with potato and the regular application of the bioagents for disease management.

The seedlings of potato, maize, sorghum were raised in pots for 15, 30 and 45 days duration. Ten seedlings from each viz. 15, 30 and 45 days of sowing were uprooted separately along with entire root system and washed thoroughly in running water followed by sterile distilled water and then left for exudation for 24 hours in sterilized conical flasks containing sterile distilled water such that, each flask received roots of 10 seedlings in 20 ml of sterile distilled water.

The effect of root exudates on germination of spores of bioagents was tested, by slide germination. Each exudate was diluted to have different concentrations, *viz.*, undiluted stock solution (100%), 1:10 and 1:20 dilutions. A drop of each concentration was placed on a clean slide separately and on which the spores of bioagents so as to get around 25-30 spores per microscopic field were transferred for germination studies. Three replications were maintained for treatment.

These slides were incubated in a moist chamber and observed for germination under microscope at an interval of 2 h keeping sterile distilled water as control and per cent spore germination was calculated.

IV. EXPERIMENTAL RESULTS

The experiment on the wilt of potato caused by *Sclerotium rolfsii* were conducted in the Department of Plant Pathology, University of Agricultural Sciences, Dharwad.

The results thus obtained are presented here under.

Survey on incidence of wilt of potato

A roving survey was conducted during *Kharif* 2004 in the districts of Dharwad and Belgaum to find out the incidence of the disease and the data are presented in the Table 1.

Table 1. Incidence of potato wilt caused by *Sclerotium rolfsii* in Belgaum and Dharwad districts during *Kharif* 2004.

The disease incidence was severe in both the districts of Dharwad and Belgaum. However, the incidence was moderate where the crop was raised under irrigation and also where the crop was intercropped with maize.

The disease incidence in Dharwad ranged from 2 to 28 per cent in different locations surveyed. The maximum disease incidence of 28 per cent was recorded in Pudukalkatti village while, minimum incidence of 2 per cent was recorded in Nadakatti.

The disease incidence in Belgaum ranged from 5 to 30 per cent in different locations surveyed. The maximum disease incidence of 30 per cent was recorded in Ujgav, while, minimum disease incidence of five per cent was recorded in Kamkratti and Halga each.

The maximum (13.86%) average disease incidence was recorded in Belgaum while, least (12.37%) in Dharwad.

Survey on tuber rot of potato

A survey was conducted during harvesting of potato in 2004 to know the incidence of tuber rot of potato in Dharwad and Belgaum and the data are presented in Table 2 and Plate 1.

Table 2. Infection of tuber rot caused by *Sclerotium rolfsii* in Belgaum and Dharwad districts during *Kharif* 2004.

Plate 1. Photograph showing tuber infection.

The tuber to in both Dharwad and Belgaum was found severe during *Kharif* 2004.

The tuber rot in Dharwad ranged from 8 to 40 per cent in different locations surveyed. The maximum tuber rot of 40 per cent was recorded in Pudukalkatti. While, minimum tuber rot of 8 per cent was recorded in Nadakatti.

Tuber rot in Belgaum ranged from 15 to 43 per cent in different locations surveyed. The maximum tuber rot of 43 per cent was recorded in Vjgav while minimum tuber rot of 15 per cent was recorded in Turmuri and Halga.

Generally the tuber rot was less in Dharwad (24.00%) than that in Belgaum (27.27%).

Isolation of fungus

The fungus was isolated (Plate 2) from different plant parts and also from soil on a PDA and the fungus isolated from the collar region was selected for further studies.

Plate 2. Pure culture of *Sclerotium rolfsii*.

Identification of the pathogen

The pathogen was identified based on morphological characters mentioned below.

The fungus produced white, dense radiating mycelial growth on PDA. In early stages of growth, the mycelium was silky white, it gradually lost its lusture and became dull in appearance and colonies grew radially. Sclerotial initials were observed from 6th day onwards. At the initial stage, the bodies were white in colour later they turned buff brown colour and than to chocolate brown at maturity. Matured sclerotia were spherical to ellipsoidal. The fungus isolated from the affected plant tissue was compared with the type species originally described and was found resembling with to *S. rolfsii* in all morphological characters.

Table 1. Incidence of potato wilt caused by *Sclerotium rolfsii* in Belgaum and Dharwad districts during Kharif 2004.

Sl. No.	Name of district	Name of place	Per cent wilting	Average (%)
1	Dharwad	Malapur	14.00	12.37
		Kamalapur	10.00	
		Neeralakatti	5.00	
		Garag	12.00	
		Tadakod	20.00	
		Hangarki	8.00	
		Nadakatti	2.00	
		Pudakalkatti	28.00	
2	Belgaum	Kadoli	8.00	13.86
		Agaska	29.00	
		Ambavadi	15.00	
		Jafrawadi	12.00	
		Halga	5.00	
		Mastmaradi	15.00	
		Tarihal	12.00	
		Kamkratti	5.00	
		Devagiri	13.00	
		Kakati	12.00	
		Desur	6.00	
		Turmuri	8.00	
		Ujgav	30.00	
		Gojgav	18.00	
Konivadi	20.00			

Symptomatology

The symptoms of wilt of potato (Plate 3 and 4) produced by *S. rolfsii* infected plant showed characteristic yellowing of leaves followed by loss of vigour. Wilted plant was easily pulled out from the soil. There was whitish mycelial growth creeping around the collar, region root as well as the infected tubers. On such tubers, white to creamy coloured, round to spherical sclerotial bodies were seen. Heavily infected tubers revealed characteristic soft rot and decaying of tissue.

Plate 3. Photograph showing symptoms of *Sclerotium* wilt.

Plate 4. Photograph showing Sclerotial bodies of *Sclerotium* wilt.

Proving pathogenicity

The pathogenicity test of *S. rolfsii* to potato was proved by soil inoculation method, carried out under glasshouse conditions as per the procedure described in 'Material and Methods'. Control was maintained without adding any inoculum.

Pathogen infected first at collar region. Leaves of such infected plants become pale green followed by yellowing. During the advanced stage of infection the white mycelium grew around the collar region and completely covered it. The base of the stem was constricted and



Plate 1. Photograph showing tuber infection.

Plate 1. Photograph showing tuber infection



Plate 2. Pure culture of *Sclerotium rolfsii*

Plate 2. Pure culture of *Sclerotium rolfsii*

Table 2. Infection of tuber rot caused by *Sclerotium rolfsii* in Belgaum and Dharwad districts during Kharif 2004.

Sl. No.	Name of district	Name of place	Tuber incidence (%)	Average (%)
1	Dharwad	Malapur	25.00	24.00
		Kamalapur	19.00	
		Neeralakatti	18.00	
		Garag	30.00	
		Tadakod	30.00	
		Hangarki	22.00	
		Nadakatti	8.00	
		Pudakalkatti	40.00	
2	Belgaum	Kadoli	20.00	27.27
		Konivadi	40.00	
		Gojgav	30.00	
		Turmuri	15.00	
		Tarihal	20.00	
		Halga	15.00	
		Ambavadi	28.00	
		Agaska	42.00	
		Mastmaradi	26.00	
		Jafrawadi	21.00	
		Ujgav	43.00	

turned brown. The plant gradually dried and toppled. The sclerotial bodies were formed on infected parts. The fungus was reisolated from affected plant tissue and compared with the original culture.

Screening of cultures of potato against *Sclerotium* wilt

Available cultures were screened in a sick plot of Department of Plant Pathology, University of Agricultural Sciences, Dharwad during 2004 as described in 'Material and Methods'. The data are presented in Table 3 and 4, Fig. 1 and 2, Plate 5 and 6.

Table 3. Reaction of early maturing cultures to wilt of potato caused *S. rolfsii*.

Table 4. Reaction of medium maturing cultures to wilt of potato caused *S. rolfsii*.

Fig 1. Reaction of early maturing cultures to wilt of potato caused *Sclerotium rolfsii*.

Fig 2. Reaction of medium maturing cultures to wilt of potato caused *Sclerotium rolfsii*.

Plate 5. Photograph showing wilt incidence in early maturing culture.

Plate 6. Photograph showing wilt incidence in medium maturing culture.

It was found that none of the cultures tested showed immune or resistant reaction to the sclerotium wilt. However, only two cultures of early maturing group viz., K-Jawhar and J/92-164 have shown 22.00 and 20.00 per cent of disease incidence respectively and considered susceptible reaction. Remaining have shown highly susceptible reactions



Plate 3. Photograph showing symptoms of *Sclerotium* wilt.

Plate 3. Photograph showing symptoms of *Sclerotium* wilt



Plate 4. Photograph showing Sclerotium bodies of *Sclerotium rolfsii*

Plate 4. Photograph showing Sclerotium bodies of *Sclerotium rolfsii*

Table 3. Reaction of early maturing cultures to wilt of potato caused by *S. rolfsii*.

Sl. No.	Early maturing cultures	Diseases incidence (%)	Disease reaction
1	K. Ashoka	60.00	Highly susceptible
2	J/93-4	77.00	Highly susceptible
3	J/92-13	77.00	Highly susceptible
4	J/92-167	50.00	Highly susceptible
5	K. Jawhar	22.00	Susceptible
6	J/93-81	70.00	Highly susceptible
7	J/93-139	50.00	Highly susceptible
8	J/94-90	80.00	Highly susceptible
9	J/93-58	70.00	Highly susceptible
10	J/92-159	80.00	Highly susceptible
11	J/92-164	20.00	Susceptible

Similarly all the medium maturing cultivars evaluated recorded highly susceptible reaction to the disease.

Management of Sclerotium wilt of potato by organic amendments bioagents and chemicals

A pot experiment was conducted during 2004 *Kharif* in a sick pot to evaluate the effect of organic amendments, bioagents and chemicals as explained in 'Material and Methods'. Observations were recorded on the per cent disease incidence and the results are presented in table 5-7.

Table 5. Effect of organic amendments on wilt of potato caused by *S. rolfsii*.

Table 6. Effect of bioagents on wilt of potato caused by *S. rolfsii*.

Table 7. Effect of fungicides on wilt of potato caused by *S. rolfsii*.

Organic amendments

Among different organic amendments tested (Table 5) significantly lowest disease incidence of 20.00 per cent was recorded in neem cake with and without oil. This was followed by neem leaf (40.00%) and pongamia leaf (40.00%) which were on par with each other but, significantly superior over other treatments. Maximum disease incidence of 100 per cent was recorded in control.

Bioagents

Among the different bioagents evaluated (Table 6) against *S. rolfsii*, significantly lowest disease incidence was recorded by both *Trichoderma harzianum* and *T. viride* (20.00%). The next best treatment was *Pseudomonas* sp. (46.60%) followed by *T. virens* and *T. koningii* (60.00%). The maximum disease incidence was recorded in control (100.00%).

Chemicals

It was obvious from the Table 7 that, there was a significant effect of chemicals on per cent disease incidence. Significantly, the lowest disease incidence was recorded in both carboxin and contaf (20.00%) which were on par with each other. The next best treatments

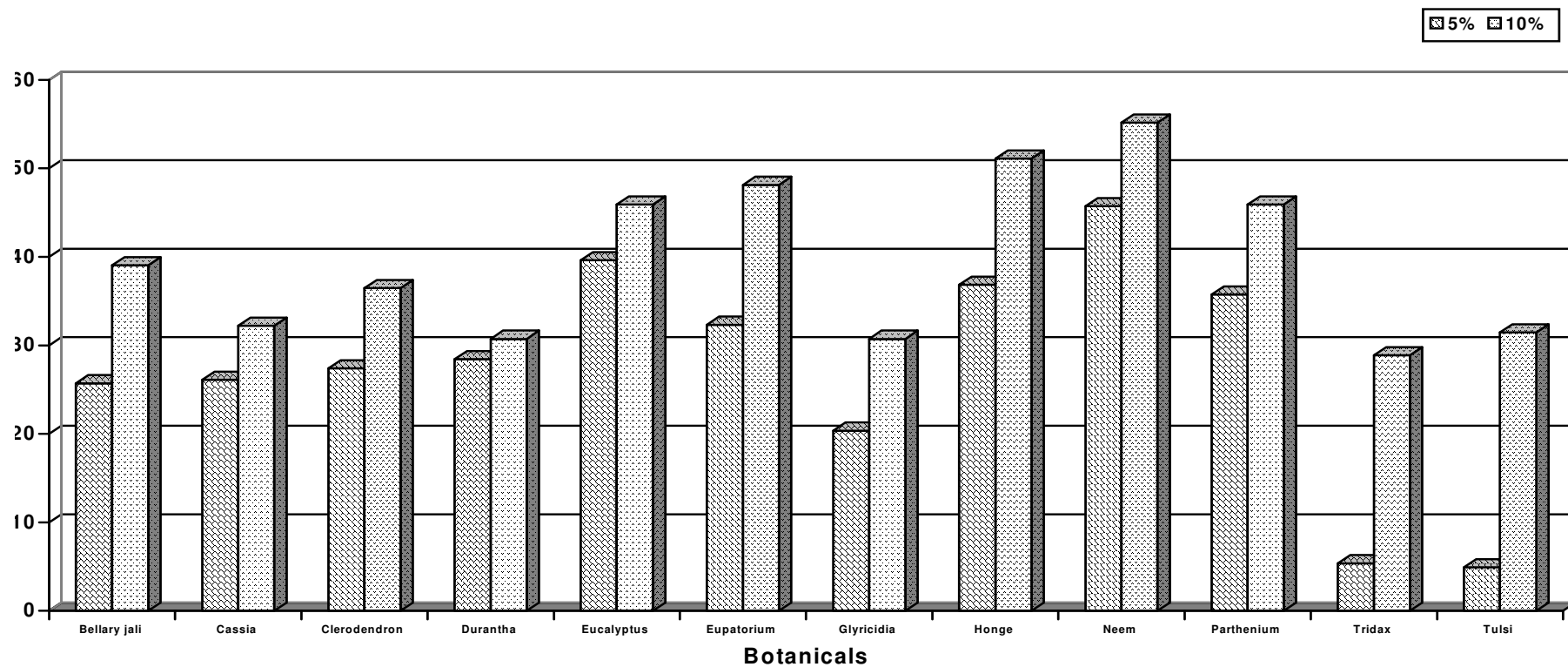


Fig 1. Reaction of early maturing cultures to wilt of potato caused by *S. rolfsii*.

Table 4. Reaction of medium maturing cultures to wilt of potato caused by *S. rolfsii*.

Sl. No.	Medium maturing	Per cent disease incidence	Disease reaction
1	MS/94/899	70.00	Highly susceptible
2	K. Anand	70.00	Highly susceptible
3	MS/95-117	80.00	Highly susceptible
4	MS/92-1090	88.00	Highly susceptible
5	MS/93-1344	80.00	Highly susceptible
6	K. Pularaj	50.00	Highly susceptible
7	MS/95-1039	60.00	Highly susceptible
8	MS/94-1118	100.00	Highly susceptible
9	JW-160	88.00	Highly susceptible
10	JX -576	90.00	Highly susceptible

were Baylaton (33.30%) followed by Bavistin and Tilt (40.00%). The maximum disease incidence was recorded in control (100.00%).

Effect of root exudates

Root exudates of different crops viz., potato, maize and sorghum were tested against spore germination of bioagents as explained in 'Material and Methods'. The observations were recorded and data are presented in Table 8 and 9, Fig. 6 and 7.

Table 8. Effect of root exudates on spore germination of *T. harzianum*.

Table 9. Effect of root exudates on spore germination of *T. viride*.

Fig 6. Effect of root exudates on spore germination of *T. harzianum*

Fig 7. Effect of root exudates on spore germination of *T. viride*

Effect of root exudates collected from the seedlings after 15 days of sowing

Trichoderma harzianum

It is clear from the Table 8 (Fig. 6) that the effect of root exudates, on germination of bioagents was significant. Significantly least germination of 29.00 per cent was recorded in stock solution (100.00%) of sorghum root exudates. As the dilution increased i.e., 1:10 and 1:20 the per cent germination also increased and recorded 33.66 and 36.66 per cent germination respectively. Similarly in case of maize root exudates, 51.00 per cent germination in stock solution, (100.00%), 56.33 and 60.00 per cent spore germination was recorded in 1:10 and 1:20 dilutions respectively. On the contrary it was found that the root exudates of potato was enhancing the spore germination and maximum of 90.00 per cent spore germination was recorded in stock solution (100.00%) followed by 82.66 per cent germination

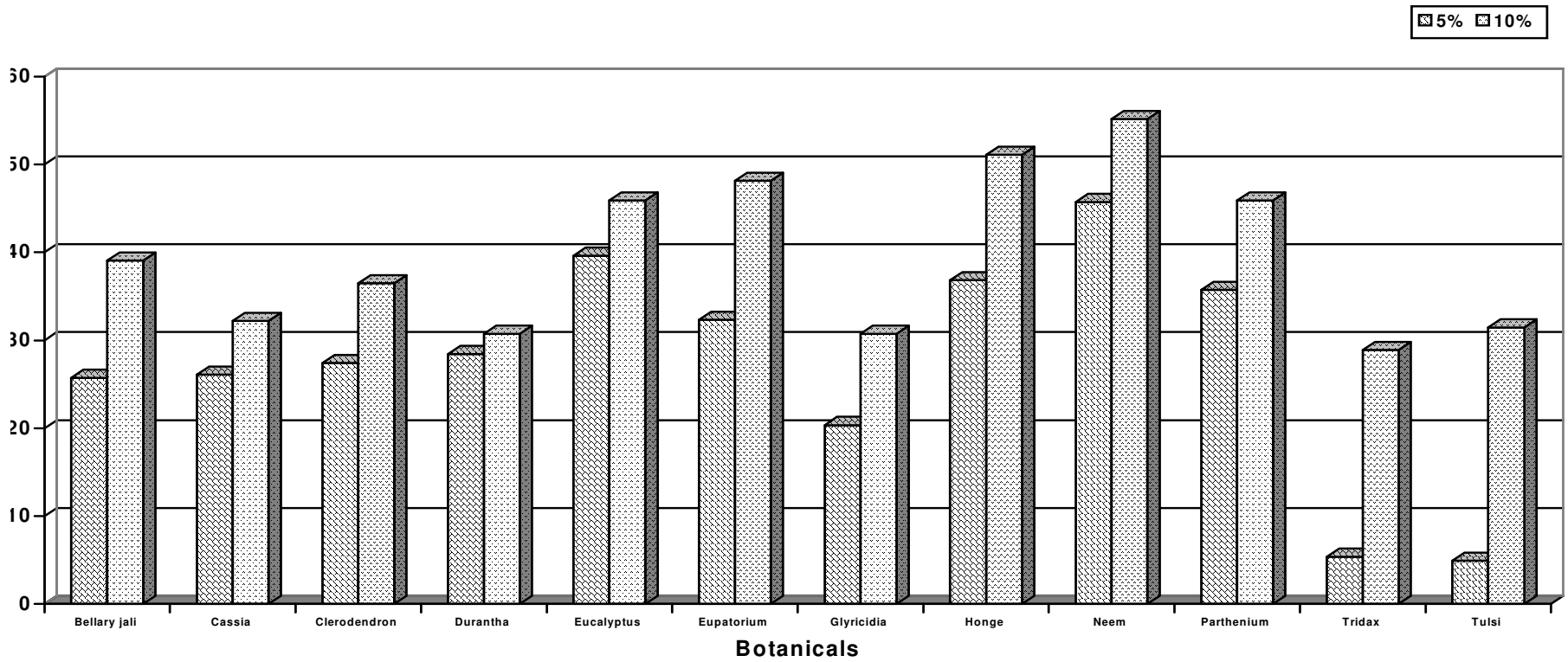


Fig 2. Reaction of medium maturing cultures to wilt of potato caused by *S. rolfsii*.



Plate 5. Photograph showing wilt incidence in early maturing cultures.

Plate 5. Photograph showing wilt incidence in early maturing cultures



Plate 6. Photograph showing wilt incidence in medium maturing cultures.

Plate 6. Photograph showing wilt incidence in medium maturing cultures

in 1:10 and 70.00 per cent germination in 1:20 dilutions as compared to control (Sterile distilled water) which recorded 65.00 per cent of spore germination.

Trichoderma viride

Similar trend was observed (Table 9 and Fig. 7) in case of *T. viride* as that of *T. harzianum*. It was observed that, sorghum root exudates were significantly least supportive for the germination under different concentrations viz., stock solution (100.00%), 1:10 and 1:20 recording 29.00, 32.33 and 38.00 per cent of spore germination, respectively. This was

Table 5. Effect of organic amendments on wilt of potato caused by *S. rolfsii*.

Sl. No.	Treatments	Concentration	Disease incidence (%)
1	<i>Adathoda indica</i> leaves	(30 g/kg of soil)	(60.00)* 50.77**
2	<i>Azadirachta indica</i> leaves	(30 g/kg of soil)	(40.00) 32.23
3	<i>Parthenium hysterophorus</i> leaves	(30 g/kg of soil)	(60.00) 50.77
4	<i>Pongamia glabra</i> leaves	(30 g/kg of soil)	(40.00) 39.23
5	Neem cake with oil	(20 g/kg of soil)	(20.00) 26.57
6	Neem cake without oil	(20 g/kg of soil)	(20.00) 26.57
7	FYM	(25 g/kg of soil)	(53.00) 46.57
8	Vermicompost	(20 g/kg of soil)	(53.30) 46.29
9	Control	-	(100.00) 90.00
	SEm±		1.696
	CD (5%)		5.083

*Show original values.

**Figures in parentheses shows angular transformed values.

followed by maize root exudates where 48.00, 53.66, 62.00 per cent spore germination was recorded in above mentioned concentrations respectively. But, potato root exudates had enhancing effect on the spore germination of *T. viride* as in case of *T. harzianum* and significantly highest spore germination of 91.00 per cent was recorded in stock solution (100.00%) followed by 1:10 and 1:20 dilutions which recorded 86.66 and 72.33 per cent respectively as compared to control (68.00%).

Effect of root exudates collected from the seedlings after 30 days of sowing

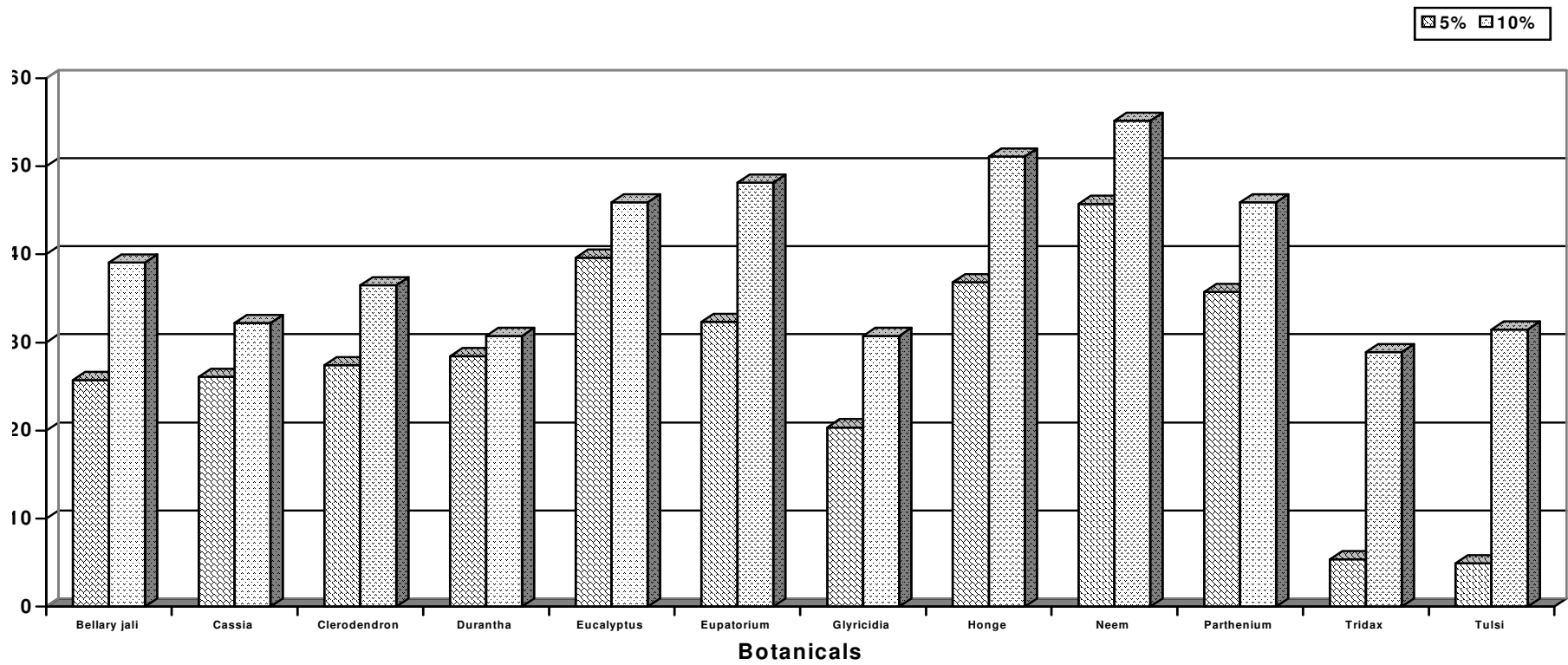


Fig 3. Effect of organic amendments on wilt of potato caused by *S. rolfsii*

Table 6. Effect of bioagents on wilt of potato caused by *S. rolfsii*.

Sl. No.	Treatments	Concentration	Disease incidence(%)
1	<i>Pseudomonas</i> sp.	10 g/l of water	(46.60)* 36.06**
2	<i>T. harzianum</i>	10 g/l of water	(20.00) 26.57
3	<i>T. virens</i>	10 g/l of water	(60.00) 50.77
4	<i>T. viride</i>	10 g/l of water	(20.00) 26.57
5	<i>T. koningii</i>	10 g/l of water	(60.00) 50.77
6	Control	-	(100.00) 90.00
	SEm±		1.292
	CD (5%)		4.215

*Show original values.

**Figures in parentheses shows angular transformed values

Trichoderma harzianum

The root exudates collected (Table 8 and Fig. 6) from the plants after 30 days of sowing also followed the same trend as that of root exudates collected from plants after 15 days of sowing, with more acute effect. The root exudates of sorghum were significantly most effective in inhibiting the spore germination at all concentrations tested. Significantly, least spore germination of 15.00 per cent was recorded in stock solution (100.00%) this was followed by 1:10 and 1:20 dilutions which recorded 18.00 and 18.66 per cent spore germination respectively but were on par with each other. Similarly, maize root exudates of different concentrations viz. 100.00 per cent, 1:10 and 1:20 recorded 39.00, 41.33 and 53.66 per cent of spore germination respectively which differed significantly with one another.

However the root exudates of potato had significant enhancing effect on per cent spore germination in all the concentrations tested. Significantly, the highest spore germination of 92.66 per cent was recorded in stock solution (100.00%), followed by 85.00 and 74.66 per cent spore germination in 1:10 and 1:20 dilutions respectively which also differed significantly.

Trichoderma viride

Similar pronounced effect (Table 9 and Fig. 7) of root exudates collected from seedlings after 30 days of sowing was observed in *T. viride* also. In case of sorghum the least spore germination of 17.00 per cent was recorded in stock solution (100.00%) and was on par with 1:10 dilution which recorded 18.66 per cent spore germination, followed by 1:20 dilution which recorded 24.00 per cent germination and differed significantly. This was followed by

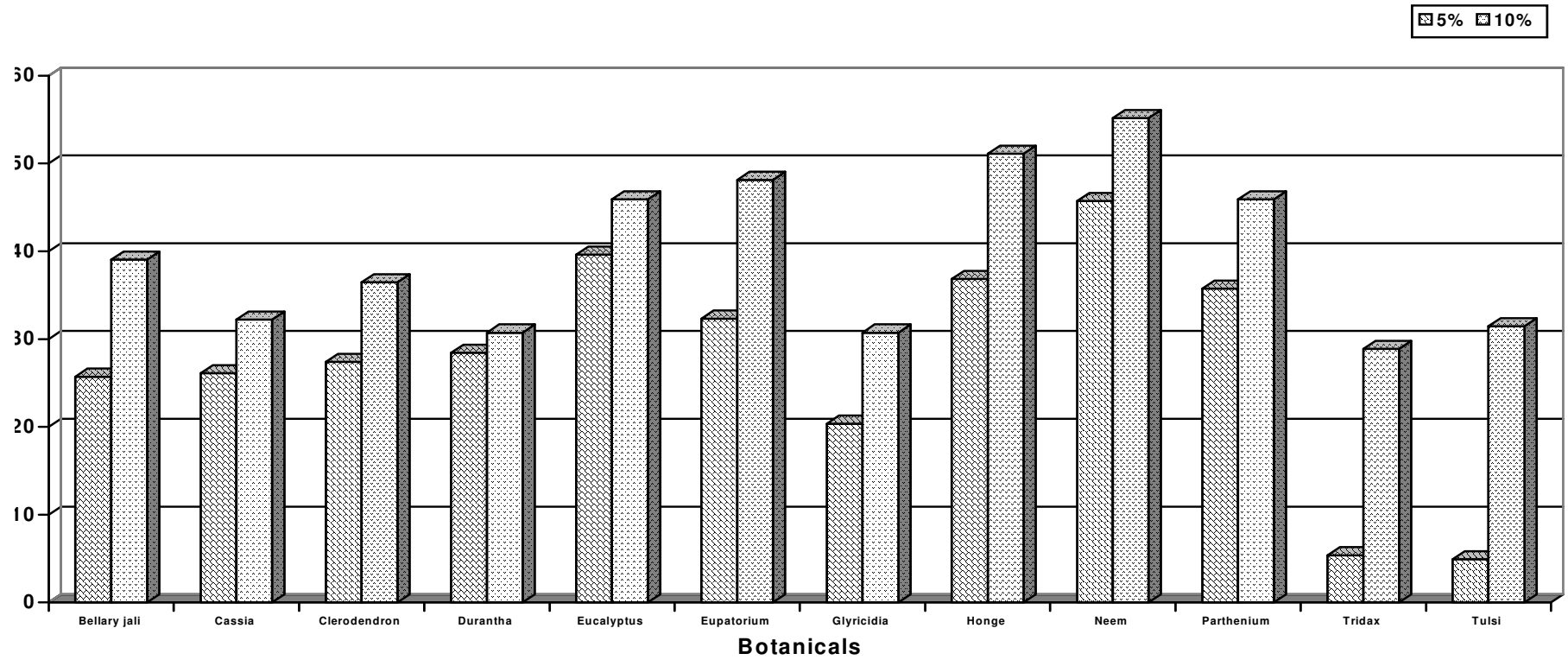


Fig 4. Effect of bioagents on wilt of potato caused by *S. rolfsii*.

Table 7. Effect of fungicides on wilt of potato caused by *S. rolfsii*.

Sl. No.	Treatments	Concentration	Disease incidence(%)
1	Captan	0.2%	(60.00)* 50.77**
2	Carbendazim	0.1%	(40.00) 39.23
3	Carboxin	0.05%	(20.00) 26.57
4	Emisan	0.1%	(60.00) 50.77
5	Hexaconazole	0.1%	(20.00) 26.57
6	Metalaxyl M-Z	0.2%	(60.00) 50.77
7	Propiconazole	0.1%	(40.00) 39.23
8	Triademefon	0.1%	(33.30) 35.01
9	Control	-	(100.00) 90.00
	SEm±		1.407
	CD (5%)		3.893

*Show original values.

**Figures in parentheses shows angular transformed values

maize root exudates which recorded 37.00 per cent germination in stock solution (100.00%) followed by 1:10 and 1:20 dilutions which recorded 40.33 and 55.33 per cent germination respectively. In contrast, the potato root exudates supported the per cent spore germination and significantly maximum spore germination of 93.66 per cent was recorded in stock solution (100.00%), followed by 1:10 and 1:20 dilutions which recorded 90.00 and 76.66 per cent respectively and differed significantly. The spore germination in control was 68.00 per cent.

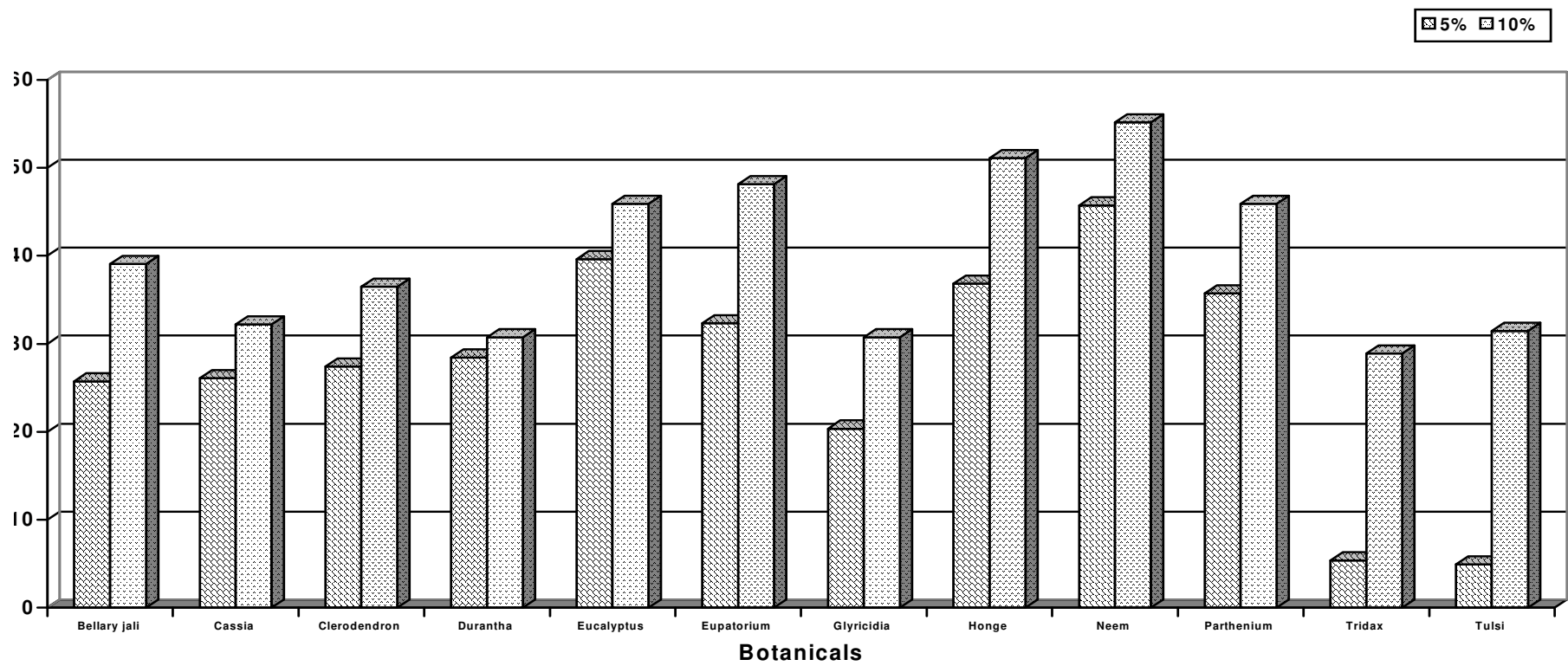


Fig 5. Effect of fungicides on wilt of potato caused by *S. rolfsii*.

Effect of root exudates collected from seedlings after 45 days of sowing

Trichoderma harzianum

The results indicated that (Table 8 and Fig. 6), the root exudates collected from seedlings after 45 days of sowing from sorghum and maize were just marginally inhibitive as that of root exudates collected from seedlings after 30 days of sowing. Least spore germination of 13.00 per cent was recorded in stock solution (100.00%) and was found significantly superior compared to 1:20 concentration. Least germination of 21.00 per cent was observed in stock solution (100.00%) of maize followed by 1:10 and 1:20 concentration. Similarly in case of potato root exudates collected from plants after 45 days of planting has reduced the spore germination as compared to the root exudates collected from seedlings after 15 and 30 days of planting. Significantly the highest spore germination 76.00 per cent was recorded in stock solution (100.00%), followed by 1:10 and 1:20 dilutions which recorded 73.00 and 68.00 per cent respectively, which differed significantly and were comparable to control 65.00 per cent germination.

Trichoderma viride

Similar trend was observed (Table 9 and Fig. 7) with significantly least spore germination of 16.33 per cent in stock solution (100.00%) of sorghum and significantly maximum spore germination of 70.00 per cent was observed in potato at stock solution (100.00%). Similar to *T. harzianum* the potato root exudates collected from seedlings after 45 days of planting were also found to have reduced in their efficiency in improving the spore germination of *T. viride* when compared with 15 and 30 days root exudates. The spore germination obtained in stock solution (100.00%) of potato was comparable with control, showing stabilizing effect at 45 days of sowing.

Table 8. Effect of root exudates on spore germination of *T. harzianum*.

Sl. No.	Crops	Concentration	Per cent spore germination in root exudates collected from seedlings of different age groups		
			15 DAS	30 DAS	45 DAS
1	Sorghum	1:20	(36.66)* 37.26**	(18.66) 25.59	(15.66) 23.05
		1:10	(33.66) 35.46	(18.00) 25.09	(13.66) 20.83
		100	(29.00) 32.58	(15.00) 22.78	(13.00) 21.12
2	Maize	1:20	(60.00) 50.76	(53.66) 47.10	(29.66) 32.99
		1:10	(56.33) 48.64	(41.33) 40.01	(23.66) 28.86
		100	(51.00) 45.57	(39.00) 38.64	(21.00) 27.27
3	Potato	1:20	(70.00) 56.79	74.66 59.80	(68.00) 55.55
		1:10	(82.66) 65.41	(85.00) 67.22	(73.00) 58.69
		100	(90.00) 71.58	(92.66) 74.43	(76.00) 60.67
4	Control	-	(65.00) 53.73	(65.00) 53.73	(65.00) 53.73
	SEm±		0.466	0.743	0.479
	CD (1%)		1.87	2.98	1.92

*Show original values.

**Figures in parentheses shows angular transformed values

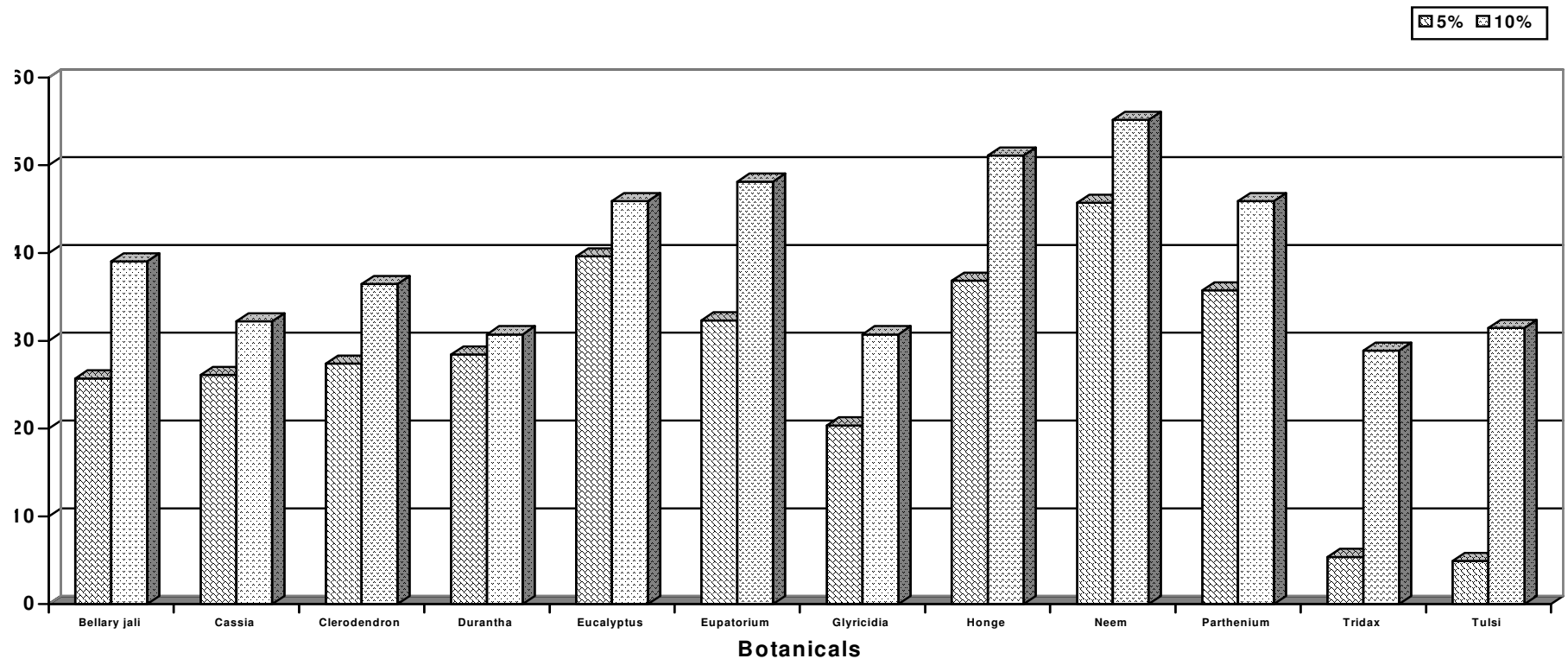


Fig 6. Effect of root exudates on spore germination of *T. harzianum*

Table 9. Effect of root exudates on spore germination of *T. viride*.

Sl. No.	Crops	Concentration	Per cent spore germination in root exudates collected from seedlings of different age groups		
			15	30	45
1	Sorghum	1:20	(38.00)* 38.05**	(24.00) 29.33	(24.00) 29.33
		1:10	(32.33) 34.64	(18.66) 25.59	(19.00) 25.83
		100	(29.00) 32.58	(17.00) 24.34	(16.33) 23.82
2	Maize	1:20	(62.00) 51.94	(55.33) 48.06	(36.66) 37.26
		1:10	(53.66) 47.10	(40.33) 39.46	(31.00) 33.83
		100	(48.00) 43.85	(37.00) 37.46	(24.00) 29.33
3	Potato	1:20	(72.33) 58.27	(76.66) 61.12	(68.00) 55.55
		1:10	(86.66) 68.60	(90.00) 71.58	(68.00) 55.55
		100	(91.00) 72.56	(93.66) 75.49	(70.00) 56.79
4	Control	-	(68.00) 55.55	(68.00) 55.55	(68.00) 55.55
	SEm±		0.534	0.624	0.446
	CD (1%)		2.14	2.50	1.79

*Show original values.

**Figures in parentheses shows angular transformed values

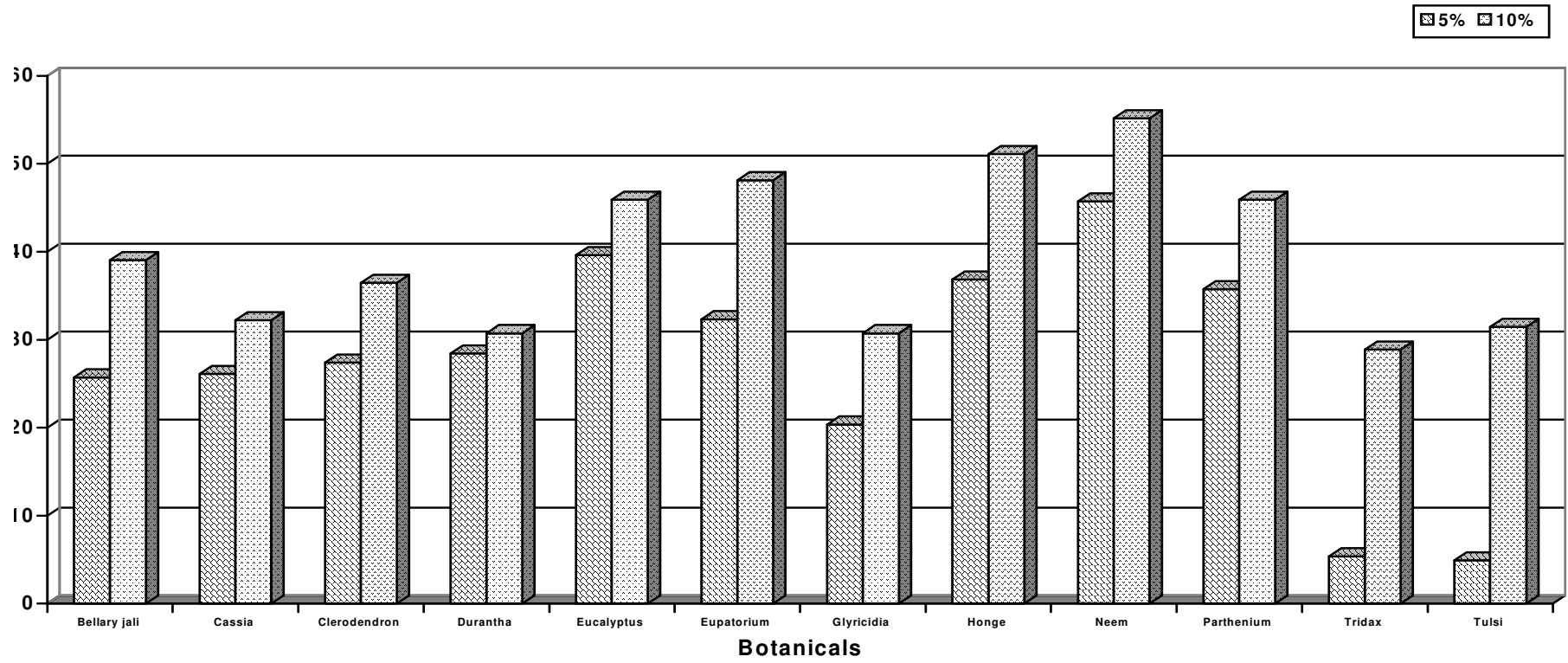


Fig 7. Effect of root exudates on spore germination of *T. viride*

V. DISCUSSION

Potato is an important commercial vegetable grown in India on an area of 1.23 m ha with a production of 23.50 m tonnes with a productivity of 19.10 t/ha during the year 1998-99. Karnataka is one of the important potato growing state in peninsular India. Such an important commercial vegetable crop is suffering from many diseases caused by various pathogens, which in turn reduce the yield. Among the fungal diseases, wilt of potato caused by *Sclerotium rolfsii* is one of the most important soil-borne disease and was first reported in 1915 from Bengal in India. The pathogen being soil-borne, it is difficult to achieve economic control of resultant disease by chemicals. Added to this, the fungus is known to be a serious pathogen on many crops of economic importance (Aycock, 1966).

Sufficient work on the management of this disease particularly by organic amendements has not been carried out on potato. So, there is a need to take up the investigation on the various aspects of disease which ultimately leads to the management of the disease. This includes the isolation, identification of the pathogen and proving the pathogenicity.

In recent years use of organic amendment is gaining importance, since it minimizes the cost of cultivation, avoids the health hazards and also eco-friendly in nature. Hence, work was carried out to evaluate some of the organic amendements against *S. rolfsii*, which in turn may indicate the use of such amendements in the management of plant diseases. Investigation was also carried out to evaluate the root exudates of certain crops on the germination of spores of effective bioagents which gives information regarding survival of bioagents after crop rotation with cereals used in integrated disease management.

The diseased specimens were collected and isolation was made. The fungus showed white, dense, radiating mycelium. Sclerotial initials were noticed six days after incubation, which were white in colour at beginning, later they turned to brown and chocolate brown at maturity. Fully matured sclerotia were spherical to ellipsoidal and measured 0.5 to 1.75 mm in diameter. Fungus produced characteristic white, abundant, mycelial growth on the infected parts. Large number of sclerotial bodies were observed on mycelial mat. These were superficial on the infected plant parts. Morphological characters on PDA Petriplates and infected tissue are in agreement with the results of the earlier workers (Saccardo, 1911 and Punja, 1985).

Pathogenicity test was carried out under pot culture condition in glasshouse by inoculating with pathogenic culture of *S. rolfsii*. Infected plant showed slight yellowing of leaves. Pathogen infected the stem and produced the dark brown lesion at collar region causing wilt and ultimately plants get dried. White mycelium was seen on roots and tubers also. Such infected plants when pulled out from the soil only shoot portion came out leaving the tubers in soil. Spherical sclerotial bodies were found and were chocolate brown in colour. The symptoms produced were in agreement with description given by Bisht (1982), Khanna and Sharma (1993), Kulkarni *et al.* (1995) and Somani and Chauhan (1996).

In the present study efforts were made to locate the resistant sources to *S. rolfsii* in potato, but with limited success. In the present investigation early and medium maturing cultivars were subjected to screening to know their reaction to *S. rolfsii*. None of the cultivars tested was found immune or resistant in both early and medium maturing groups. In case of early maturing JS/92-164, K. Jawhar have shown susceptible reaction with a wilting of 20 and 22 per cent respectively and rest of the cultivars / genotypes showed highly susceptible reaction (Anahosur, 2001).

Among medium maturing cultivars none of them have shown resistant or immune reactions and all have shown highly susceptible reactions.

Sources of resistance against this pathogen appears to be rare event. Since it is weak and opportunistic parasite. We may come across by some cultivars, which may possess certain level of resistance, if not immune, by frequent screening activity involving broad genetic base.

A roving survey was conducted in potential potato growing tracts of Dharwad and Belgaum, to know the wilt incidence. During the survey it was observed that average wilt incidence was maximum in Belgaum (13.86%) followed by Dharwad (12.37%).

The maximum wilt incidence was recorded in Ujgav (30.00%) in Belgaum. In Dharwad the maximum wilt incidence was observed in Pudukalkatti (28.00%). This results are in accordance with Anahosur and Kulkarni (1997).

To know the incidence of tuber infection, a roving survey was conducted in potato growing areas of Dharwad and Belgaum at the time of harvesting. Average tuber infection was maximum (27.27%) in Belgaum than in Dharwad (24.00%). In Belgaum maximum tuber infection of 43 per cent was recorded in Ujgav. In Dharwad the maximum tuber infection was recorded in Pudukalkatti (40.00%) and minimum in Nadakatti (8.00%) villages. This results are in accordance with Anahosur and Kulkarni (1997).

Use of organic amendments to control soil borne diseases of plants is a effective non-chemical method and indirect approach to control the pathogen. Organic amendments not only reduce the disease intensity but also increase the antagonists, soil fertility and crop yield to a considerable extent.

In the present study, neem cake with oil and neem cake without oil proved to be more effective in reducing the disease incidence. Addition of oil cakes proved to be more effective in reducing the disease than crop residues. Various biochemicals, including antibiotics and phenols, released during decomposition of lignin containing materials, induce disease resistance on the root surface as well as in the tissues when absorbed. The results thus obtained are in accordance with the reports of Nishatkhalis and Manoharachary (1985), Padmodaya and Reddy (1999), Rajan *et al.* (1991), Goudar *et al.* (1998), Karunanithi *et al.* (2003) and Padmodaya (2003). In the present study the next effective organic amendments were neem leafs and pongamia leaf, which kept the activity of *S. rolfsii* at low level. This results are in agreement with the findings of padmodaya and Reddy (1999), Ram and Tewari (1994) and Karunanithi *et al.* (2003). This was followed by FYM and vermicompost which also kept the pathogen at low level. Similar results were reported by Mathur and Sinha (1970), Lingaraju (1977), Palakshappa (1986), Padmodaya and Reddy (1999) and Gurjar *et al.* (2003).

The effect of organic amendments on pathogenic fungi may be attributed due to release of ammonia (NH₃) that is directly toxic to sclerotia. These amendments having high C:N ratio after decomposition results in an increase in the microbial population and activity of antagonistic microbes. Hence, there is a considerable amount of carbon dioxide gas liberation by these soil saprophytes, which suppressed the pathogenic activity of *S. rolfsii* in the soil (Punja, 1985).

Biocontrol through the use of antagonistic micro-organisms is a potential non-chemical means for plant disease management because of its advantages like, low cost, long lasting, non-polluting and eco-friendly. Tuber treatment with antagonist helps to check the disease incidence to a greater extent.

In the present study the tuber treatment with *Trichoderma harzianum* and *T. viride* shown significantly less disease incidence. This effect of *Trichoderma* sp. may be due to direct attack and lysis of mycelium of *S. rolfsii*.

Mycoparasitism is the mechanism of action of *Trichoderma* on *Sclerotium*, were in it is going to invade and parasites the mycelia. Elad *et al.* (1980) reported that, the application of *T. harzianum* to the root zone of tomato controlled *S. rolfsii* in naturally infested soil and on transplanting the treated plants showed the reduced disease incidence by 93 per cent and yield increased by 100 per cent. The results thus obtained are in accordance with the reports of Saraswathi and Pal (1986), Kulkarni and Kulkarni (1994), Virupaksha Prabhu *et al.* (1997), Anahosur *et al.* (1998b), Biswas and Sen (2000), Bari *et al.* (2000), Biswas and Sen (2000), Anahosur (2001), Alonso *et al.* (2002), Ram and Bhanushally (2003), Narsimha Rao *et al.* (2004) and Fateh Singh *et al.* (2004).

The next best treatment was *Pseudomonas* sp. which can colonise the root system and produce the antagonistic secondary metabolites such as siderophores and antibiotics like phenazines, pyrroluterin and pyrrolnitrin. *Pseudomonas* will produce siderophores which are

low molecular weight ferric iron transport agent. The function of siderophores is to supply iron to the bacterial cell. These siderophores will transfer the iron from rhizosphere to pseudomonas and make it unavailable to the other rhizoplane microorganisms, including plant pathogens, hence the population of pathogen is reduced. *Pseudomonas* sp. has reduced the wilt incidence. Similar results were obtained by Wokocha *et al.* (1986), Rajendra *et al.* (1998), Sheela *et al.* (1998).

Evaluation of certain fungicides was also done to know their antifungal activity against *S. rolfsii*.

In the present investigation carboxin and hexaconazole have reduced the wilt incidence. Similar effects in reducing the disease incidence was reported by Maiti and Choudhari (1975), Pal and Choudhary (1983), Harlapur and Srikant Kulkarni (1992), Viswakarma and Basu (1982), Tiwari and Singh (2004).

The next best treatments in reducing wilt incidence were triademefon followed by carbendazim. Similar results were obtained by Siddaramaiah *et al.* (1979), Harlapur and Kulkarni (1992), Vanitha and Suresh (2002) and Tiwari and Ashok (2004).

The present investigation was carried out to find out effect of root exudates on *T. harzianum* and *T. viride* which were found effective in controlling *Sclerotium* wilt.

It was observed that, among the root exudates tested, sorghum root exudates was more detrimental to *T. harzianum* and *T. viride*, followed by maize root exudates. This may be attributed due to the production of water soluble toxic substances such as Hydrocyanic acid which has suppressive effect on the fungus (Bose, 1938). Similar effect of root exudates on some other fungi like *Sclerotium rolfsii* was reported by Narashima Rao (2000) and Anahosur (2001).

Further it was observed that toxic substances present in root exudates of both sorghum and maize were higher, when collected from seedlings of 30 days of sowing, than at 15 day of sowing. Similar effect was obtained by Satish-Mehta *et al.* (1992) when the root exudates collected 30 days after germination of cowpea has higher phenols than at 15 days after germination.

In contrast to the above results, the root exudates of potato supported the spore germination of *T. harzianum* and *T. viride*. Similarly Hillocks *et al.* (1997) reported the germination of chlamydo spores of *F. oxysporum* f. sp. *udum* (But.) was stimulated by their host (cotton and pigeonpea) root exudates. Anahosur *et al.* (1998) also reported the root exudates of groundnut supported the sclerotial germination under *in vitro*.

This enhancing effect of root exudates of potato was shown upto 30 days of sowing and decreased their after. This effect may be due to stimulatory factor associated with this particular exudates.

Out come of result

The experiment carried out has great significance, during survey it come to know that *Sclerotium* has great threat to potato cultivation, among the screened cultivars none of the cultivars have shown resistant reaction, but some cultivars recorded least disease incidence which can be used for further breeding programme. In the management study among organic amendment neem cake, in bioagents *Trichoderma harzainum* and among fungicides carboxin recorded the least disease incidence.

Future line of work

1. There is a need to take integrated approach by organic amendments, bioagents and chemicals for the management of sclerotium wilt of potato.
2. Need to under take intensive studies on root exudates of other cereal crops.
3. There is a need to isolate, identify and characterize the compound which is involved in inhibition of *Trichoderma* spp.
4. There is a need identify the resistant source in potato against sclerotium wilt.

5. There is a need to conduct dual culture technique to find out efficient strain of bioagents and organic amendments *in vitro*.

VI. SUMMARY

Potato (*Solanum tuberosum* L.) is one of the most important commercial vegetables cultivated in northern Karnataka. Many biotic factors limit the potato production. Among the biotic factors, fungal diseases are major constraints in reducing the yield. Wilt of potato caused by *Sclerotium rolfsii* Sacc. is attaining the major status in potato in Karnataka.

Hence, detailed studies on this pathogen including survey, isolation, identification, symptomatology, proving pathogenicity, screening, management by organic amendments, bioagents, chemicals and evaluation of root exudates of certain crops on bioagents were made. The information obtained in the current investigation is summarized here under.

A survey was conducted in potential potato growing areas of Dharwad and Belgaum in *Kharif* to know the wilt incidence. Maximum wilt incidence of 30.00 per cent was recorded in Ujgav village of Belgaum.

Survey for tuber rot was carried out during harvesting and the maximum tuber rot of 43 per cent was recorded in Ujgav of Belgaum.

The fungus was isolated from the rhizosphere of wilted plant, later it was identified based on white dense radiating mycelium both in culture and infected plants.

Potato plants were raised in an inoculated pots and after 6th week a pure culture of *S. rolfsii* was obtained from wilted plants showing typical wilting symptoms and pathogenicity was proved successfully.

Among the early and medium maturing cultivars screened against *S. rolfsii*, only JS/92-164, K. Jawhar have shown the least disease incidence (20-22%) which are of early maturing and remaining all have shown high disease incidence or highly susceptible reactions.

Studies on management of wilt of potato revealed that, among organic amendments, neem cake with oil and neem cake without oil, among the bioagents *T. harzianum* and *T. viride* and among chemicals carboxin and bayleton were found the best in reducing the disease incidence.

Among the root exudates tested, sorghum and maize root exudates were found detrimental to bioagents (*T. harzianum* and *T. viride*). Whereas, potato root exudates were found stimulatory.

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STUDIES ON POTATO WILT CAUSED BY *Sclerotium rolfsii* Sacc.

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ABSTRACT

Potato (*Solanum tuberosum* L.) is one of the most important commercial vegetable crops cultivated in northern Karnataka. Wilt of potato caused by *Sclerotium rolfsii* Sacc. is exerting the major threat in potato cultivation in Karnataka.

A roving survey was conducted in potential potato growing areas of Zone 8 (Dharwad and Belgaum districts). Maximum wilt incidence (30.00%), and maximum tuber rot (43.00%) were recorded in Ujgon village of Belgaum.

The fungus was isolated from the rhizosphere of wilted plant and identified based on white dense radiating mycelium in culture and infected plants.

Potato plants were raised in an inoculated pots and pure culture of *S. rolfsii* was obtained from wilted plants showing typical wilting symptoms and pathogenicity was proved successfully at the same time symptomatology was studied.

Among the early and medium maturing cultivars screened against *S. rolfsii* only JS/92-164 and K. Jawhar of early maturing group recorded least disease incidence of 20-22 per cent and rest of all the cultivars tested recorded high disease incidence.

Studies on management of wilt of potato revealed that, among organic amendments, neem cake with oil and neem cake without oil, among the bioagents *Trichoderma harzianum* and *T. viride* and among the fungicides Carboxin (0.05%) and Hexaconazole (0.1%) as tuber treatment recorded least disease incidence of 20.00 per cent, which were found to be the best in reducing the disease incidence.

Among the root exudates tested, sorghum and maize root exudates were found detrimental to *Trichoderma harzianum* and *T. viride*, whereas, potato root exudates were found stimulatory.