STUDIES ON CORM ROT OF SAFFRON (*Crocus sativus* L.)

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CERTIFICATE - I

This is to certify that the thesis entitled "**Studies on Corm Rot of Saffron (*Crocus sativus* L.)**"submitted in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Agriculture (Plant Pathology), to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology (Kashmir) is a record of bona-fide research work carried out by **Mohammad Azam Wani** (Registration No. 97/A/53/D) under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation has duly been acknowledged.

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ABSTRACT

A major bottleneck in the successful cultivation of saffron (*Crocus sativus* L.) in Kashmir has been the wide spread occurrence of corm rot. The incidence and intensity of the disease ranged from 4.00 to 40.00 per cent and 0.80 to 16.93 per cent, respectively in 1999 and, 4.66 to 42.00 and 1.33 to 17.46 per cent in 2000 in surveyed saffron growing fields. Collectively the corm rot severity was more in district Pulwama than in Budgam and Anantnag districts. Maximum corm rot infestation during both the years was observed in the corms collected at digging state. The disease in the field is characterized by wilting and drooping of saffron plants, having yellow dull foliage and tip burn symptoms. On digging out

the infected corms showed dark brown sunken, irregular lesions, frequently on buds which generally coalesce. The affected plants had less number and undersized daughter corms and flowers besides reduction in the flowering period. Three *Fusarium* spp. viz. *F. solani, F. moniliforme* and *F. oxysporum* have been found associated with the disease and their pathogenicity was also established. However, *F. solani* was most prevalent and destructive and was regarded as the principal pathogen. This was the only species isolated from the infected corms collected at digging and harvesting stages. While other two species isolated only from infected corms collected at storage stage but there too *F. solani* was the most predominant. Association of nematodes with *Fusarium* propagules was invariably encountered in the corm rhizopheres in all the saffron growing fields. The saffron fields of Pulwama district had higher population count of both nematodes and *Fusarium* spp. as compared to Budgam and Anantnag districts. Simultaneous rhizosphere inoculation of nematodes and *F. solani* produced the maximum corm rot infestation and significantly reduced the saffron yield as compared to un-inoculated check or inoculation of either nematode or fungal pathogen.

Three non-chemical disease management approaches involving the use of bioagents, organic amendments and soil solarization were investigated in polyethylene bag. All resident bioagents viz. *Trichoderma viride*, *Trichoderma harzianum, Gliocladium virens* and *Asperigillus niger* in *in vitro* ,inhibited the growth of pathogen to varying degrees but *T. viride* exhibited highest antagonistic affect and showed strong volatile and non-volatile inhibition activity as compared to other bioagents. However, *T. viride* and *G. virens* were equally effective in reducing the

corm rot to appreciable levels when tested as soil treatment. Among the various organic amendments, decomposed FYM, poultry manure and mushroom compost suppressed corm rot and enhanced the yield of saffron. These organic amendments in general enhanced soil fungal population and reduced the population of pathogenic fungi with maximum effect due to FYM and poultry manure (4:1 w/w) amendments. Amendments in general, exhibited stronger protection at higher level (4:1 w/w) then at lower dosages (5:1 w/w).

Soil solarization for 6 weeks during mid June to July increased the soil temperature in sick soil at 5 cm depth by 8.4 and 8.9^0C during 2000 and 2001, respectively. While as for 4 weeks, the rise in temperature during corresponding period was 6.5 and 6.4^0C. The corm rot intensity in such plots was significantly suppressed during both the years of experimentation. Among the solarized treatments, highest disease reduction was achieved with 6 weeks solarization after irrigation and amending the soil with FYM in the ratio of 4:1 w/w (soil: FYM).

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

CHAPTER-I

INTRODUCTION

Saffron (*Crocus sativus* L.), a golden condiment and a legendary crop belongs to family Iridaceae. It is extensively grown in upland and karewa areas of Kashmir valley and parts of Kishtwar in Jammu Division. Initially saffron has been a prime crop of Pampore and adjoining areas but now its cultivation is being extended to many other suitable areas of district Anantnag and Budgam (Fig.1). Experimental

cultivation of saffron has also been undertaken in Himachal Pradesh and Uttaranchal but Jammu & Kashmir remains a leading state as for as area and production of saffron in India is concerned. The State of Jammu & Kashmir has near monopoly in this crop.

Saffron is also cultivated in China,, England, Iran, Italy and Spain. Geographically, its cultivation is confined to 0^0-90^0 longitude and 30^0-45^0 N latitude and it is believed to have originated in Greece, Asia minor and Persia from where it is believed to have spread towards Kashmir valley and China (Warburg, 1957).

Saffron is a perennial field crop, the corms of which perenate underground for six to seven years in the field and progress geometrically in terms of corm number and flower production. The mother corm once planted multiplies every year by producing daughter corms and each corm produces one flower. The crop warrants replanting when the space between the two mother plantings gets occupied by daughter corms. The planting in fresh area is done in the month of August and the crop initially gives out flowers followed by foliar growth during autumn and winter and the foliage dries down during summer (Plate I).

The medicinal and other uses of dry saffron of commerce are very well known and documented. The saffron of commerce has lot of utility in confectionary, pharmaceutical industry and therefore, the crop is considered “a high value low volume” produce.

In Jammu & Kashmir State, an area of 5361 hectares is estimated to be under this crop with a production of 173.82 quintals worth 43 crores annually (Anonymous, 1997). The productivity per hectare at present has been estimated to range from 2.79 to 3.24 kg but a yield ranging from 6-8 kg/ha area is reported from countries like Iran, Italy and Spain (Zargar, 2002).

The average productivity in Jammu & Kashmir State is reported to be declining year after year. As against productivity of 3.7 kg ha^{-1} in 1977, the production has declined to 2.70 kg ha^{-1} in 2002. The decline in production continues though the newer areas are brought under its cultivation.

Several factors have been identified to be the cause of decline in productivity. Frequent drought or drought like situations during active period of corm multiplication, inadequate after care of the crop, lack of balanced nutrition and above all the incidence of many biotic factors are

the major constraints in harvesting the maximum flower yields. Among the biotic factors, damage caused by rats, rodents and other hibernating animals in saffron field can not be ignored. However, the major problem encountered is in the form of rotting of corms which do not permit their further multiplication and thus leads to reduction in per unit area corm number and the yield.

Rotting of corms is evident when the saffron fields are visited as considerable areas in such fields are barren. When the area in question is dug out, raminants of rotten dead corms are clearly visible. Partially rotten corms are also observed when seed corms are usually dug out for fresh planting in newer areas. This unique problem has attracted attention of saffron growers and the Government agencies, besides the concerned disciplines of Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar.

At times the problem gets reflected in many important development and administrative forums. Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar initiated a research project “Improving Productivity and Post Harvest Handling and Develop Quality Standards of Saffron” as a lead centre under NATP

Project, Govt. of India, New Delhi. The problem is of very serious nature and any amount of research work put in saffron have not lead to any substantial breakthrough. Therefore, further studies were taken up to investigate the problem in detail and systematic manner so as to understand the causes and methods of overcoming the damage, to help in increasing the productivity with the objectives given below and the findings arrived at, comprise the body of this thesis.

- To know the present status of the disease in the valley.
- To identify the causal pathogen(s) associated with the disease.
- To make detailed studies in management of the disease.

CHAPTER-II

REVIEW OF LITERATURE

Saffron (*Crocus sativus* L.) is a prize crop, wonder of nature and gift to mankind. The crop though grown in limited area of a few countries of world, is not spared by disease causing organisms world over. Since literature available on corm rot of saffron is very scarce, hence studies carried out on related diseases of other crops have also been reviewed for the purpose of present investigations.

2.1 Occurrence

Bilgrami *et al.* (1981) compiled and updated the list of fungal flora available in India, were not able to record the occurrence of any fungus from India on saffron corms, foliage or saffron of commerce. According to Zadoks (1981) Duttamel in 1728 gave the first experimental evidence of corm diseases in his published paper "The treatise on the violet root rot of *Crocus*". However, survey of literature revealed that dry rot of corm was first noticed in Kyota district of Japan by Abe (1933) and since then its occurrence has been made from many saffron growing countries of the world. Prevalence of this disease has been reported from USA, Canada, UK, Holland, Germany and New Zealand (Drayton, 1934), Spain and France (Madan *et al.*, 1967), Japan (Yamamoto *et al.*, 1956), Spain (Alarcon and Sanchez, 1968), Italy (Carta *et al.*, 1982, Cappelli *et al.*, 1991, Cappelli, 1994) and China, (Xu and Ge, 1990). From India this disease was first reported by Shah and Srivastava (1984) from Chabautia, Almora (UP) and later on by Thakur *et al.* (1992) from Kishtwar in Jammu region and Dhar (1992) from Pampore in Kashmir.

2.2 Status of disease

According to Abe (1933), the dry rot disease in Japan was mostly noticed during May and June, when the digging of the saffron corms attempted. Alarcon and Sanchez (1968) noticed severe crop losses in Spain due to saffron corm rot. Zadoks (1981) reported that the saffron cultivation has to be abandoned in France and England partly because of frequent outbreaks of this disease. Severe damage to the crop due to disease in Italy has also been reported by Cappelli (1994). In the most severely affected areas of Italy, Cappelli *et al.* (1991) found 40-50% corms infected with dry rot disease. From India, Thakur *et al.* (1992) recorded disease incidence in the range of 30-40% in Kishtwar Jammu division. Dhar (1992) reported that none of the saffron growing areas in Kashmir valley were found free from the disease and recorded disease incidence in the range of 6.7 to 15.2%. However, Thakur (1997) reported the corm rot incidence to the magnitude of 70-80% from saffron growing fields of Kashmir. Cappelli and Minco (1999) considered the disease as the major limiting factor of stigma yield of saffron in Italy.

2.3 Causal organism

Literature reveals conflicting reports about the causal pathogen/pathogens associated with the corm rot. The fungal nature of the disease was first reported by Abe (1933) and identified the causal fungus as *Fusarium bulbigenum* var *blasticola* but Francesconi (1974) has found *Pencillium cyclopium* involved in the corm rot disease in Italy. Recently Guzhen *et al.* (1997) from China described the causal fungus as *Penicillium corymbiferum.* However, Cappelli (1994) from Italy, and Shah and Srivastava (1984) from India identified causal fungus as *F. oxysporium* f.sp. *gladioli.* Dhar (1992) found *F. moniliforme* var. *intermedium* and an unsporulating basidiomycetous fungi associated with the disease. But Cappelli and Donato (1994) isolated *Fusarium oxysporium and Penicillium corymbiferum* from the severely damaged corms. However, Sud *et al.* (1999) has reported *F. solani* as the causal agent of saffron corm rot from the Himachal Pradesh. Recording the disease and pest status of saffron in the Spain and France, Madan *et al.* (1967) found *Rhizoctonia crocorum* (*Helicobasidium crocorum*) and *Phoma crocophila* responsible for causing the rot diseases of corms but earlier Zadoks (1981) found *Rhizoctonia crocorum* as the only

pathogenic fungus associated with the disease in the saffron belts of France. However, earlier Alarcon and Sanchez (1968) reported *Sclerotinia bulborum* besides *R. crocorum* as the causal agents of the rot disease in saffron fields of Spain.

Carta *et al.* (1982) from Sarvonia (Italy) and Thakur *et al.* (1992) from Jammu (India) isolated *Macrophomina phaseolina* from the rotted corms. Similarly, Mir *et al.* (1989) from Kashmir isolated *Trichoderma polysporum* from the infested corms. However, Thakur (1997) reported that many fungal pathogens like *Pythium* spp., *Rhizoctonia* spp., *Phoma* spp., *M. phaseolina* and *F. solani* are associated with the corm dry rot.

The bacterial nature of saffron corm rot has been reported by Xu and Ge (1990) from China and identified the strain of *Pseudomonas gladioli* as the cause of disease. However, earlier Mizusava (1923) had identified the causal bacterial species as *Bacillus croci* from Japan.

Besides dry rot of corms, many other fungal diseases have been reported on saffron notably leaf spots due to *Septoria gladioli* (Drayton, 1928), *Sporotrichum narcissie* (Tochinai and Shimada, 1930), white mould due to *Sclerotinia gladioli* (Drayton, 1934), root rot due to *Pythium ultimum* (Tomilinson, 1952), bulb rot due to *Botrytis tulipae*

(Weber, 1924), blue mould due to *Penicillium crocicola* (Yamamoto *et al.,* (1956), smut disease due to *Urocystis gladiolicola* (Boerema and Van Kestern, 1961), charcoal rot due to *Macrophomina phaseolina* (Carta *et al.,* 1982 and Ionita *et al.,* 1995). All these diseases have been reported to inflict heavy crop losses either singly or in association with the dry rot diseases.

2.4 Symptomatology

While studying the infection, Madan *et al.* (1967) noted that the pathogenic fungi responsible for corm rot usually attacks the corms after penetrating through protective sheaths and transforms the flesh of corms from white to yellow and ultimately to black resulting death and destruction of the invaded corms. Besides above symptoms Shah and Srivastava (1984) even observed chloritic lesions on the leaves of saffron plants affected with corm rot fungus. Cappelli *et al.* (1991) reported that the disease is characterized by poor growth and wilting of saffron plants besides damping off, basal stem rot, drooping and wilting of shoots. Dhar (1992) while observing the corm rot symptoms, noted that symptoms were exhibited in the form of brown to dark sunken irregular patches at any point of infection below the corm scales, lesions usually 1mm deep,

have raised margins and mostly located in root and the bud regions, affected corms showed yellow foliage after bloom and got detached easily. Detailed disease symptoms has also been reported by Thakur (1997) and according to him the rotting is dry and there is no symptoms of corm softening and dry depressed, brownish to black coloured spots appears at advanced stage of infection. Detailed symptoms and environmental relationship of fungal corm rot have also been presented by Carta *et al.* (1982) and that of bacterial dry rot by Xu and Ge (1990).

2.5 Predisposition

Poor soil aeration due to water stagnation, injuries due to transplanting and hailstorm has been reported to be predisposing the host to fungal infection (Anonymous, 1988). Excessive soil moisture during hot summer months have been found favourable for the development and spread of the corm rot disease in Kashmir especially when untimely showers are received by the crop in the field (Anonymous, 1988). Francesconi (1974) observed damaged corms as most susceptible to the disease and found warm temperatures and damp conditions favourable for disease development. Earlier, Weber (1924) had reported that over 70 per cent humidity helps in disease development. While studying the

infection, Abe (1933) noted that incidence and severity of infection in saffron corm was much higher in arid than in humid soils and reached to maximum at soil temperature of 32^0C but at below 20^0C the symptoms were negligible. He recorded optimum temperature for mycelial growth as 28^0C and pH ranging from 3.5 to 5.6.

2.6 Management

2.6.1 Organic soil amendments

Several workers have described the addition of organic amendments as one of the effective methods of management of soil borne diseases.

The effect of decomposing crop residues and other organic additions on fungal pathogens are stimulating and inhibitory depending upon the source and age of residues (Meir, 1959 and Synder *et al.*, 1959).

While working on effects of oil cakes on general population of *Fusarium* sp., in soil, Bhalla (1966) observed the pathogenic fungal population decreased with the use of organic soil amendments especially at higher temperatures.

Jordan *et al.* (1972) observed significant decrease in the number of viable propagules of *Verticillium dahlie* in the soil and in disease severity

of strawberry when organic soil amendments were used. It has been observed that Hardwood bark compost suppressed *Phytophthora cinnamoni* root rot pathogen (Hoitink *et al.*, 1976). While studying the effect of oil cake amendments on the pigeon pea wilt pathogen, Singh and Singh (1982) noticed that the inhibitory effect against pathogen increased with the gradual decomposition of oil cakes. Khalis and Manoharachary (1985) studied the changes induced by oil cake amendments in mycoflora of coriander soil and recorded increase in the population of antagonistic fungi and complete disappearance of *F. solani*. Sun *et al.* (1989) observed that the use of S-H mixture as a organic soil amendments reduced the *Fusarium* diseases of watermelons, melons, peas and radishes; *Phytophthora* blight of cucumber and bacterial wilt of tomatoes. Singh *et al.* (1990) reported that soil amendments with inorganic and organic sources of nitrogenous manures proved beneficial in the management of root rot in sesame crop.

Lukade (1992) evaluated the effect of different organic soil amendments on root rot of safflower and got encouraging results with decomposed FYM and straws of wheat and paddy tested @ 2 per cent. Lazarovits (2001) reported that the organic amendments containing

higher nitrogen, such as poultry manure, meat and bone meal and soy meal significantly reduced populations of wide spectrum of soil borne plant pathogens. Karthikeyan (1996) reported that the organic amendments (FYM, sheep manure and poultry manure) significantly reduced seed and collar rot of groundnut. Ringer *et al.* (1997) reported well rotten organic manures like poultry, dairy and horse dung composts suppressed damping off causing by *Pythium* spp. and *Rhizoctonia* spp. Rajan and Sharma (2000) reported organic soil amendments proved effective against foot rot of pepper.

Sharma and Sharma (2002) in their studies on the effect of oil cakes and on the soil microbial population in relation to *Dematophora necatrix* causing root rot of apple recorded increased population of antagonistic fungi (*Aspergillus*, *Penicillium* and *Trichoderma* spp.) with concomitant decrease in white root rot in the amended soils.

2.6.2 Biological control

Biological methods of plant disease management mainly involve the usage of micro-organisms to check the harmful micro-organisms that cause plant diseases without disturbing the ecological balance. Such effects were made during 1920-1930, but the success was limited. Many

seminars and symposiums were held to understand the phenomena of biocontrol (Mukhopadhyay, 1994). The first book entitled “Biological Control of Plant Pathogens” was authored by Baker and Cook (1974). This was followed many other books written by other authors. In the recent past dramatic increase in research efforts in biological control of plant diseases in India was observed.

Roy (1977) reported the parasitic activity of *T. viride* on sheath blight fungus of rice. Upadhyay and Mukhopadhyay (1983) reported the inhibitory effect of *T. harzianum* on the growth of *Sclerotium rolfsii.* Similarly, Mukhopadhyay and Kaur (1990) too recorded the inhibitory effect of *T. harzianum* on *Rhizoctonia solani* besides *F. oxysporum.* Sawant and Mukhopadhyay (1990) recommended the integration of metalaxyl with *T. harzianum* for control of *Pythium* damping off in sugar beet. Beale and Pitt (1990) from their studies on the biological and integrated control of *Fusarium* basal rot of *Narcissus* concluded that the disease could be managed by treating the bulbs with *Minimedusa polyspora* and *Streptomyces* sp. or with *M. polyspora* and *Thiobendizole.* Use of biological control agents along with solarization have been reported to provide synergistic effect in reducing incidence of many plant

diseases (Mohapatra and Dash, 1990; Rao and Krishnaappa, 1995 and, Ristaino *et al.*, 1996). Application of *T. hamatum* reduced the Aubergene wilt to 38 per cent followed by *T. viride* compared to 74 per cent observed in untreated check (Sheela *et al.*, 1995). Thakur (1997) observed combined treatment of saffron corms before sowing with selected fungicides and antagonistic micro-organisms (*Trichoderma viride; T. harzianum* and *Gliocladium virens* and three *Bacillus* spp.) much more effective and economical in the corm rot disease management. Anith *et al.* (2000) reported that the integration of soil solarization and biological control agents produced positive effect on the management of bacterial wilt of ginger. Dubey and Patel (2001) evaluated successfully the fungal antagonists like *T. viride; T. harzianum* and *Gliocladium roseum* against *R. solani* causing web blight of urd and mung bean.

2.6.3 Soil solarization

Soil solarization has been investigated by a number of workers for controlling soil borne plant pathogens, insect pests and weeds.

Katan (1980) described soil solarization management method a safe and non-chemical, does not produce phytotoxic residues, is

relatively inexpensive and simple to use. Katan *et al.* (1983) studied the effect of soil solarization and reported that the treatment resulted in reducing the fungal population in soil, decreased wilt incidence, depressed *Fusarium* wilt and increased crop yields for as long as three years after treatment. Population of soil born fungal and bacterial pathogens remained significantly depressed in solarized soil after 6-12 months (Stapleton and Devay, 1982). Dwivedi and Dubey (1987) observed that maximum temperature in polyethylene sheeted soil with full sunlight at a depth of 1 cm reduced the inoculum of *Macrophomina phaseolina.*

Chauhan *et al.* (1988) reported the effects of soil solarization in *Fusarium* wilts of pigeon-pea and chickpea. They observed that soil solarization increased mineralization of soil nitrate but decreased the population of *Fusarium* spp. and plant parasitic nematodes. Incidence of wilt of chickpea caused by *Fusarium oxysporum* f. sp. *Ciceri* was reduced by soil solarization as compared with that of crops grown in non-solarized soils (Arora and Pandey, 1989). Satish and Lodha (1989) observed that solar heating reduced the population of *Macrophomina phaseolina* in arid soils. They recorded reduction of 57-81 per cent and

21-64 per cent at 15 cm and 30 cm soil depths respectively due to increase in soil temperature by using soil solarization. Arora *et al.* 1989) reported that solarization of soil resulted into marked reduction of propagules of *Fusarium solani* and weeds in their field experiments.

According to Lozarovits *et al.* (1991) solarization is an effective soil dis-infestation procedure for the top 10 cm of soil. The population level of the tomato pathogen *Fusarium oxysporum* f.sp. *lycopersici* in soil progressively declined after 10, 20 and 30 days of soil solarization treatment (Dwivedi, 1991). Lodha, 1995 concluded that solarization together with amendment of soil with neem cake or organic matter reduced diseases caused by soil borne fungi and nematodes.

2.6.4 Chemical control

Madan *et al.* 1967) reported that the corm rot disease could be avoided by choosing good healthy corms for planting and by peeling off the outer most protective sheaths besides giving cormlets a bath in 5 per cent solution of copper sulphate. Alarcon and Senchez (1968) suggested the use of pentachloronitrobenzene (PCNB) @ 300 kg/ha to ward off the damage inflicted to crop by corm rot fungi (*R. crocorum* and *S. bulborum*). Shah and Srivastava (1984) controlled the disease

successfully with difolatan, bavistin or benomyl, each at 0.2 per cent, by dipping the corms for 20 minutes before planting in September. Dhar (1992) achieved best results with *thiophenate methyle, c*arbendazim (0.1%), captafol and copper oxychloride 0.3%). Removal of outer sheaths of the corm and dipping in the 5 per cent $Cuso_4$ solution before planting have widely been recommended for disease management (Anonymous, 1988). Cappelli (1994) achieved disease prevention by using healthy reproductive material and recommended use of benzimidazoles in some cases.

CHAPTER-III

MATERIALS AND METHODS

For achieving the objectives of the study, experiments were conducted in grower's field in saffron growing areas of Kashmir and at the Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar from 1999-2002.

3.1 Status of the corm rot

The status of corm rot in saffron fields was quantified by taking two parameters namely incidence and intensity into account and the procedures adopted are described as under:

3.1.1 Selection of sites

Twelve locations, four each in the districts of Pulwama, Budgam and Anantnag were identified for recording the data at three stages of crop management namely corm digging (last week of July), corm storage, fifteen days after digging (Mid August) and saffron harvesting (Ist week of November). In each location, three different fields/sites were marked randomly. In all, thirty six different fields were surveyed for recording the data at periodical intervals during 1999 and 2000.

For recording the rot incidence and intensity at corm digging and storage stages, three hundred corms were picked randomly from three corm heaps at each selection site (one hundred/heap). Similarly at saffron harvesting stage, a unit area of one square metre area at three different places in a saffron bed *in situ* was selected in each site at random and from each belt one hundred corm dug out randomly for recording the rot

incidence and severity. The data collected on incidence and intensity was pooled at the end of season for each selection site during both years.

3.1.1.1 Incidence

The corm rot incidence was calculated by the following formula:

		No. of diseased corms		
Percent corm rot incidence	=	----------	x	100
		Total no. of corms observed		

3.1.1.2 Intensity

The disease intensity was calculated by categorizing the corms on the basis of their rot status/symptoms as under:

Category	Numerical value	Description
I	0	Healthy
II	1	1-20% rot
III	2	21-40% rot
IV	3	41-60% rot
V	4	61-80% rot
VI	5	81-100% rot

The disease intensity was calculated by the formula given by Horsfall and Heuberger (1942) with certain modifications.

		$\sum nV$		
Percent disease intensity (PDI)	=	----------	x	100
		N x 5		

Where

$\sum nV$ is the sum of the product of n (number) corms with rating V, N is the total number of corms assessed and 5 is the maximum rating.

3.2 Symptomatology

Symptoms exhibited by saffron plants affected by corm rot were observed throughout the growing season in selected saffron beds of Pampore. The beds were marked in the month of October and the symptoms recorded right from emergence of initial flower till digging of mature corms in the month of July next. The studies were carried out during consecutive season of 1999 and 2000 in healthy and diseased beds as:

- flower count/m^2 of cropped area of apparently healthy beds and diseased beds;
- observations on the emerging foliage with respect to colour, spotting and overall vigour;
- time taken from initial flowering to end of flowering and initial foliage emergence to foliage drying;

- number of corms per unit area of healthy and diseased beds;
- the corms showing rot symptoms and healthy were sorted out and corm rot symptoms studied for the corm size, corm colour, rot colour, status of outer tunic and root symptoms. The typical symptoms were also photographed and described.

3.3 Isolation of the fungal flora

The corms showing rot/disease symptoms were brought to laboratory in perforated polyethylene bags and subjected to identification of fungi accompanying by adopting routine laboratory methods.

3.3.1 Direct observations

Scrapings from naturally infected corms were collected upon dry glass slides with the help of a teasing needle in a drop of water and examined under low power. Hyaline fungal structures from the scrapings were examined by placing a drop of cotton blue in lactophenol. The slides thus examined provided a clue of the accompanying fungi as per conidial and mycelial characters. Accordingly the probable fungi involved were identified.

3.3.2 Examination of tissue culture fungi

The bits of rotten saffron corms were removed with the help of sharp blade at the point of junction between diseased and healthy portions and collected in sterile petriplates having sterile distilled water under aseptic conditions of Laminar clean air flow. The bits were treated with 0.1 per cent mercuric chloride for ½ minute and serially transferred in three washings of sterile distilled water and dried upon sterile blotting paper. The bits were transferred aseptically upon PDA in petriplates of 9 cm diameter, 5 in each at equidistant spaces. The plates were incubated at 25 ± 2^0C for seven days and the emergence of fungal colonies observed. The colony count was recorded and the dominating fungi observed, were bought to pure culture by routine laboratory techniques like single spore isolation and mycelial tip methods. The pure cultures were maintained on PDA and kept for observation and identification.

3.3.3 Identification of the fungi

The fungal bits along with the agar from actively growing cultures were aseptically removed and placed upon a Petri-plate containing PDA and allowed to grow in an incubator at 25 ± 2^0C for seven days and the colony characters in the form of dimensions were studied and colour on

the back of plate were recorded. The morphological characters in the form of mycelial and conidial dimensions and other structures were studied under high power microscope by placing the bits upon a drop of water or cotton blue in lactophenol. The conidial size and colouration were determined observing over 500 conidia in each case and average dimensions worked out. The characters and the dimensions observed were compared with standard texts published in monographs and journals and identity established. Cultures were sent for confirmation of the identification to Indian Type Culture Collection, Division of Plant Pathology, IARI, New Delhi.

3.3.4 Preparation of mass culture

Mass multiplication of important pathogenic fungus associated was attempted in sand maize meal medium in conical flasks. The composition of the medium was as under:

- crushed maize 136 (g);
- sand 275 (g);
- water 92 (ml).

The requisite quantity of maize meal, sand and water were thoroughly mixed to accommodate 50 flasks at a time plugged with non-

absorbent cotton and autoclaved for one hour at 15 lbs psi. The flasks were thoroughly shaken after autoclaving and cooling. The flasks were inoculated with fungal cultures from petriplates uniformly and maintained at 25 ± 2^0C for 15 days, shaking the flask at regular intervals. The culture thus multiplied was used for further studies.

3.3.5 Pathogenicity test

Apparently vigorous and healthy corms were selected for conducting the pathogenicity tests. The outer tunic/scales of each corm were removed and the corms washed with tap water and dried in shade. The corms were surface sterilized with ethanol (95%) placed upon absorbent cotton. Half of the selected corms were injured with the help of sterile needles just 1-2 mm deep around the middle portion giving 10 pricks in each corm. The injured and un-injured corm sets were immersed for one minute in spore + mycelial suspension obtained from fresh cultures raised in culture tubes after thorough mixing with sterile water. Un-inoculated, both injured and un-injured corm sets, served as check and were dipped in sterile distilled water. Both inoculated and un-inoculated corms were covered with moist sterilized cotton swab, held in place with adhesive tap, were incubated separately in humid chamber at

25 ± 2^0C for disease development and after three weeks, the symptoms were observed. Cotton swab was removed just after the appearance of the symptoms. The rotten portions were again removed from the corms inoculated artificially and the fungi isolated and compared with the inoculated fungi to prove Koch's postulates of pathogenicity. The fungus/fungi that showed the symptoms was rated as pathogenic and which did not show symptoms was considered as non-pathogenic.

3.4 Cultural studies

Three species of *Fusarium* found associated with the saffron corms that produced rot symptoms and which proved pathogenic under artificial inoculation conditions, were further studied for their growth on Richard's agar medium at periodical intervals. The three species were inoculated in the middle of petriplate and incubated at 25 ± 2^0C. Linear growth of the growing colonies was measured after 24 hours, for a period of six days and the average colony dimensions worked out.

3.5 Association of nematodes and *Fusarium* propagules in saffron rhizosphere

To get estimate of nematodes and fungal population in field of saffron crop, the random soil samples were collected from the saffron growing fields of three districts of Kashmir. A total of 12 locations were

selected, three in each district. The soil samples were taken up to a depth of 10 cms in a randomized fashion from different places of rhizosphere of saffron corms during 2000. From each location, three soil samples of 1 kg were taken in polythene bags to avoid the loss of moisture, securly tied and labeled and brought to the laboratory for the studies.

3.5.1 Population count of nematodes

The procedure for assessing the nematode population was as under:

The collected soil samples from each location were thoroughly mixed together to make a composite or bulked sample. The sub samples (250 ml) drawn from bulked sample were thoroughly suspended in water. The mixture was filtered through 20, 60 and 300 mesh sieves and the sieved retention was thoroughly washed with clean water, and kept on a modified Baermann funnel over a tissue paper. The nematodes from the filtrate were counted by aliquot dilution method under binocular stereozoom microscope.

3.5.2 Population count of *Fusarium* species

One gram of composite soil sample collected from each location was dissolved in 9 ml of distilled water by vigorously shaking in a

culture tube. The supernatant liquid was decantated and transferred to graduated tubes of the centrifuge. Liquid was centrifuged at 2500 r.p.m for 5 minutes and the supernatant liquid drops were severely diluted by dilution plate technique of Barron (1971) and population of *Fusarium* spp. were isolated by using fusarium specific medium of Nash and Synder (1962).

3.5.3 Studies on the frequency of occurrence of three *Fusarium* species at three stages of corm collection.

The studies were carried out on the infected corm samples collected from saffron fields of Regional Research Station Konibal, district Pulwama, at the three stages i.e. corm digging, storage and saffron harvest. The procedure adopted for assessing the species of *Fusarium* was the same as described in 3.3.2 and the per cent frequency of occurrence was worked out.

3.5.4 Interaction of *Fusarium solani* and nematodes on the development of corm rot and yield of saffron

Effect of *Fusarium solani*, the dominating pathogen, and nematodes on the development of corm rot was assessed by adopting the following procedure:

To study the interaction between parasitic nematodes and corm rot fungus, an experiment was laid during August – November, 2000. Surface sterilized 8 cm diam, corms were sown in soil in polyethylene bags of 21″ x 14″ size containing 4 kg steam sterilized soil and decomposed farmyard manure mixture (4:1). Six corms were maintained in each bag. There were four treatments, viz. (i) control (sand, maize meal and water only in soil) (ii) inoculation with nematode only (1000 larvae/kg soil) (iii) inoculation with fungus (50 g inoculum, prepared in sand, maize meal medium kg/soil) and (iv) inoculation with nematode + fungus. The inoculum was added 30 days after corm sowing by removing some soil from the vicinity of the root zone and was again covered with the soil previously removed. The bags were arranged in Completely Randomized Design with five replications in each treatment. After crop harvest, yield of saffron/ 10 plants was recorded and were dug out and examined for the affect upon corm colour, besides assessed for disease incidence and intensity.

3.6 Management of corm rot

Three non-chemical and non-hazardous management approaches were investigated for their role in checking the corm rot in saffron. The approaches identified were:

a. use of organic amendments;

b. use of fungal bioagents;

c. use of soil solarization.

3.6.1 Role of different organic amendments in disease management

3.6.1.1 Effect on the soil population of *Fusarium solani* and total fungi

The five organic amendments namely decomposed farmyard manure (FYM), decomposed poultry manure, mushroom compost (wheat straw based), spent mushroom compost and decomposed saw dust (willow + popular) were used for the present studies. Required quantities of organic amendments in the ratios of 4:1 and 5:1, soil amendment (w/w basis) in each case were thoroughly mixed with soils collected from saffron fields of Pampore, having known history of corm rot infestation, and inoculated with vigorously growing culture (3 weeks old) of *F. solani* multiplied on sand maize meal medium, in the ratio of 1:4 (inoculum: soil w/w). Soil + amendment mixture both infested and un-

infested were filled in polyethylene bags of 4 kg capacity. The test bags were watered frequently with rose-can and kept in open fields for a period of 45 days for proper decomposition of the material incorporated with soil. Suitable controls were maintained for comparison that is without any amendment. Population count of test fungal species, *F. solani* and total fungi was assessed separately upto 90 days at 30 days interval from each treatment using *Fusarium* specific of Nash and Snyder (1962) and Steiner and Watson (1965) agar media, respectively by dilution plate technique of Barron (1971). The data was subjected to statistical analysis for drawing the inferences.

3.6.1.2 Effect of amendments on corm rot development and yield of saffron

To study the effect of organic amendments on corm rot severity and yield of saffron, thirty corms (5/poly bag) comprising each unit of a treatment (organic amendment) were planted in polyethylene bags filled with amended inoculated soil (as mentioned in 3.6.1.1) and the corms assessed for the incidence, intensity and yield parameters. Those parameters were assessed as per the procedure described in 3.1.1.1 and 3.1.1.2. The experiment was laid in Completely Randomized Design with six treatments including check and five replications per treatment. The

observations on all the parameters in each treatment were also taken during subsequent year i.e. 2001. Un-amended un-inoculated served as check.

3.7 Antagonistic effect of bioagents on *Fusarium solani*

3.7.1 Dual culture technique

In vitro the antagonistic effect of four bioagents namely, *Trichoderma viride, Trichoderma harzianum, Gliocladium virens* and *Asperigillus niger* was studied against *F. solani* by dual culture technique using PDA medium. Discs (5mm) of the antagonist as well as the pathogen were cut with the help of sterilized core borer from the edge of the 3 days old culture and then placed apart in solidified PDA medium. Treatments were replicated five times and the plates incubated at 25 ± 2^0C in darkness for seven days. Inhibition of mycelial growth of pathogen by each antagonist was recorded on the basis of radial growth in dual culture and in control (having only pathogen) with the help of following formula:

		C-T		

1	=	----------	x	100
		C		

Where

1	=	Inhibition per cent
C	=	Radial growth in control
T	=	Radial growth in treatment

3.7.2 Volatile mechanism of bioagents against *Fusarium solani*

The volatile mechanism of the bioagents was studied as per the following procedure:

Five mm mycelial disc of actively growing cultures of the bioagents (3 days old) were placed in the centre of petriplates containing PDA. The top of each petriplate of same size was replaced with bottom of the PDA plate centrally with mycelial disc of *F. solani*. Plates with PDA medium without antagonists at the lower lid and plates inoculated with mycelial disc of the pathogen on the upper lid were maintained as controls. The pairs of each plates were sealed together with cellophane tape. The plates were incubated for 7 days at 25 ± 2^0C in darkness. The inhibition in the growth of *F. solani* in comparison to check was attributed to the volatile action of the bioagent.

3.7.3 Non-volatile mechanism of bioagents against *Fusarium solani*

The non-volatile mechanism of the bioagents was studied as per the following procedure:

100 ml of sterile potato dextrose broth was placed in 250 ml of conical flask. The broth was inoculated with measured quantities of bioagents. The flasks were incubated for 15 days at 25 ± 2^0C`. The broth was vigorously shaken and passed through three Whatman filter paper No.42 put on each other and the filtrate was collected in a sterile flasks and added to molten PDA so as to have final concentration of 10 per cent (v/v). The medium was poured into petriplates and inoculated after solidification with 5 mm discs of *F. solani*. Suitable controls were maintained without amending the culture filtrate and radial growth was recorded after 15 days and per cent inhibition calculated as per the formula given in 3.7.1.

3.7.4 Effect of bioagents on disease intensity of saffron corm rot in poly bags

In vivo effect of bioagents on corm rot intensity was studied by adopting the following procedure. Apparently healthy corms of 8 centimeter diameter were selected and cleaned in tap water and dried in shade. The corms were dipped in homogenized propagules of *F. solani* after giving 10 pricks in each corm. The corms treated were dried in

shade and kept for two weeks. The soil collected from saffron fields was sterilized in gunny bags placed in an autoclave. The sterilized soil was separately inoculated with spore suspensions of concentration of 4 x 10^7 spores per ml of each bioagent using 100 ml per kg of soil. The soil was thoroughly mixed and placed in polyethylene bags of 4 kg capacity. Each bag was planted with 6 corms which were already inoculated with *F. solani* two weeks earlier. The corms were allowed to grow and disease allowed to develop under natural conditions. The disease intensity was assessed after harvesting the saffron flower.

3.8 Effect of soil solarization on the development of corm rot in saffron

Experiment was carried out at saffron field of Pampore in poly bags during 2000 and 2001 and the procedure adopted is as under:

The experiment was laid in Randomized Block Design. Solarization was carried out for 4 and 6 weeks with 5 treatments viz:

a. soil solarization alone, covering the polyethylene bags with transparent polyethylene sheets (100 gauge thick);

b. solarization after irrigation, covering the polyethylene bags with transparent polyethylene sheets after irrigation till the soil is fully saturated;

c. application of FYM alone to polyethylene bags in the ratio of 4:1 (4 parts of soil + one part of FYM);

d. soil solarization after the application of FYM and irrigation, covering the polyethylene bags with polyethylene sheets after application of FYM in the ratio of 4:1 and irrigation till the soil is fully saturated;

e. control, no solarization for each period of solarization

Five replications were maintained in each treatment. Solarization was carried out by mulching the perforated polyethylene bags with polyethylene sheets of 100 gauges. Each polyethylene bag was filled with soil collected from the sick saffron fields having known history of corm rot and subsequently inoculated with the mass culture of the pathogen @ 200 g/bag prior to solarization treatment. Soil temperature was recorded before and after solarization at 5 and 10 cm depth at each period of solarization. The solarization was done during mid of June to end of July in both the years.

After solarization, the polyethylene bags were removed to shade and six apparently healthy corms were sown in each bag. Each treatment

was replicated five times. The data on disease incidence and intensity and, changes in soil temperature were recorded after crop harvest.

CHAPTER-IV

EXPERIMENTAL RESULTS

4.1 Status of corm rot

4.1.1 Corm rot incidence

The data on the percentage incidence of corm rot from 12 locations of Kashmir valley recorded during 1999 and 2000 is presented in Table-1 and Fig.2.

Table: 1

Incidence of corm rot of saffron at different locations in Kashmir

	Average disease Incidence (%)					
	1999		**2000**		**Mean**	
Location Stage	**L; S; Y**	**L; Y**	**L; S; Y**	**L; Y**	**L; S**	***L***
Digging	35.33 (36.46)		36.66 (37.26)		35.99 (36.86)	
Storage	18.00 (25.10)		20.66 (27.03)		19.33 (26.28)	
Zaffron colony (Pulwama)		22.88 (28.20)		24.32 (29.20)		23.60 (28.70)
Harvesting	15.33 (23.05)		15.66 (23.31)		15.49 (23.18)	
Digging	34.00 (35.66)		35.33 (36.46)		34.66 (36.86)	
Storage	18.66 (25.59)		20.00 (26.55)		19.33 (26.08)	
Lethpora (Pulwama)		23.99 (29.11)		24.66 (29.53)		24.32 (29.32)
Harvesting	19.33 (26.08)		18.66 (25.59)		18.99 (25.84)	
Digging	32.66 (34.85)		34.00 (35.66)		33.33 (35.26)	
Storage	8.00 (16.42)		5.53 (13.60)		6.76 (15.01)	
Wattan (Pulwama)		15.99 (22.32)		16.06 (22.12)		16.02 (22.22)
Harvesting	7.33 (15.70)		8.66 (17.11)		7.99 (76.40)	

Digging	40.66 (39.61)		42.00 (40.39)		41.33 (40.00)	
Storage	23.33 (28.88)		18.00 (25.10)		20.66 (26.99)	
Pampore (Pulwama)		28.88 (32.30)		29.88 (32.82)		29.38 (32.56)
Harvesting	22.66 (28.42)		29.66 (32.99)		26.16 (30.76)	
Mean			22.94 (27.98)		23.73 (28.41)	
Digging	16.66 (24.08)		18.66 (25.59)		17.66 (24.93)	
Storage	10.00 (18.43)		13.33 (21.41)		11.66 (19.92)	
Gowharpora (Budgam)		12.88 (20.92)		14.21 (22.01)		13.54 (21.47)
Harvesting	12.00 (20.26)		10.66 (19.05)		11.33 (19.66)	
Digging	13.33 (21.41)		18.00 (25.10)		15.66 (23.26)	
Storage	6.33 (14.57)		8.00 (16.42)		7.16 (25.20)	
Kultreh (Budgam)		9.44 (17.69)		11.11 (19.07)		10.27 (18.39)
Harvesting	8.66 (17.11)		7.33 (15.70)		7.99 (16.41)	

Digging	18.66 (25.59)		24.00 (29.33)		21.33 (27.46)	

Storage	11.33 (19.66)		10.00 (18.43)		10.66 (19.04)	
Qazipora (Budgam)		11.77 (19.53)		13.55 (20.90)		12.66 (20.21)
Harvesting	5.33 (13.34)		6.66 (14.95		5.99 (14.15)	
Digging	12.66 (20.84)		22.00 (27.97)		17.33 (24.41)	
Storage	12.00 (20.26)		7.33 (15.70)		9.66 (17.98)	
Wadipora (Budgam)		9.55 (17.56)		11.33 (18.71)		10.44 (18.13)
Harvesting	4.00 (11.59)		4.66 (12.46)		4.33 (12.02)	
Mean			10.91 (18.92)		12.55 (20.17)	
Digging	9.33 (17.78)		13.33 (21.41)		11.33 (19.60)	
Storage	8.33 (16.77)		10.00 (18.43)		9.16 (17.6)	
Sirhama (Anantnag)		7.88 (16.24)		10.66 (18.98)		9.27 (17.61)
Harvesting	6.00 (14.17)		8.66 (17.11)		7.33 (15.64)	
Digging	13.33 (21.41)		16.66 (24.08)		14.99 (22.74)	
Storage	9.33 (17.78)		11.00 (19.48)		10.17 (18.63)	

Khiram (Anantnag)		9.88 (18.18)		12.10 (20.22)		10.99 (19.19)
Harvesting	7.00 (15.34)		8.66 (17.11)		7.83 (16.22)	
Digging	6.66 (14.95)		10.66 (19.05)		8.66	
Storage	4.00 (11. 53)		4.66 (12.46)		4.33	
Marhama Wadur (Anantnag)		4.88 (12.69)		7.33 (15.49)		6.1 (14.08)
Harvesting	4.00 (11.59)		6.66 (14.95)		5.33	
Digging	10.00 (18.43)		16.00 (23.57)		13.00 (21.00)	
Storage	6.33 (14.57)		7.00 (15.34)		6.66 (14.96)	
Sirigopora (Anantnag)		7.77 (16.11)		10.22 (18.32)		8.99 (17.22)
Harvesting	7.00 (15.34)		7.66 (16.06)		7.33 (15.70)	
Mean		7.6 (16.12)		10.07 (18.43)		

Mean of the year		13.82 (21.24)		15.45 (22.21)	14.64 (21.66)
	Digging	20.27 (25.92)		23.94 (28.82)	22.11 (27.37)
Mean Stages	Storage	11.30 (19.13)		11.29 (19.16)	11.30 (19.15)

	Harvesting	9.89 (17.67)		11.13 (18.86)	10.51 (18.27)

	SE_M	CD at 5%
Location	1.03	2.04
Stage	0.51	1.02
Year	0.42	0.83
Location x Stage	1.79	3.54
Location x Year	1.46	2.89
Stage x Year	0.73	1.44
Location x Stage x Year	2.53	4.99

Figures in parenthesis are angular transformed values.

***Incidence CV: 14.45**

Sign: Y : Year
L : Location
S : Stage

The data indicate that corm rot was prevalent in all the locations of the three districts and at all the three stages during both the years of study. Both incidence and intensity varied significantly with location and stages. The corm rot incidence ranged from 4.00 to 40.66 per cent with an average of 13.82 per cent during 1999 and 4.66 to 42.00 per cent with an average of 15.45 per cent during 2000. Average highest incidence of 22.11 per cent was found at digging stage and lowest at harvesting stage (10.51 per cent) however, mean disease incidence at stages of harvesting and storage were statistically identical. Similarly, amongst the surveyed locations, maximum mean disease incidence (29.38 per cent) was recorded at Pampore (Pulwama) followed by Lethpora (24.32 per cent) and Zaffron colony (23.6 per cent) but comparatively minimum (6.1 per cent) at Marhama-Wudur (Anantnag). The data when subjected to interaction analysis revealed that location x stage; location x year and location x year x stage were significant. The disease status during 1999 and 2000 was statistically similar. However, the overall disease level was slightly higher during 2000 but distribution pattern was almost identical.

4.2 Corm rot intensity

The data on the corm rot intensity measured at different locations in Kashmir valley is presented in Table-2 and Fig. 3.

From the data it is clear that the difference in per cent intensity between different locations, stages and the years were significant. Corm rot intensity ranged from 0.80 to 16.93 per cent with an average of 4.25 per cent during 1999 and 1.33 to 17.46 per cent with an average of 5.5 per cent during 2000. Among the locations, mean disease intensity was maximum in Lethpora-Pulwama (10.08 per cent) and Pampore (9.49 per cent) equally followed by Zaffron colony where disease intensity of 8.48 per cent was recorded and least was observed in Marhama-Wudur (1.45 per cent).

The average mean disease intensity between different stages also varied significantly. It was highest at digging stage (8.64 per cent) followed by 3.32 per cent at storage stage and least (2.74 per cent) at harvesting stage. The interaction values were also significant. Comparatively mean disease intensity was significantly more (5.5 per cent) during 2000 and less (4.25 per cent) during 1999.

Table: 2

Disease intensity of corm rot of saffron at different locations in Kashmir

		Average disease intensity(%)					
		1999		2000		*Mean*	
Location	***Stage***	**L; S; Y**	**L; Y**	**L; S; Y**	**L; Y**	**L; S**	**L**
Digging		14.80 (22.62)		17.46 (24.69)		16.13 (23.67)	
	Storage	4.53 (12.28)		7.20 (15.56)		5.86 (13.92)	
Zaffron colony (Pulwama**)**			7.68 (15.34)		9.28 (16.85)		8.48 (16.09)
Harvesting		3.73 (11.13)		3.20 (10.30)		3.46 (10.71)	
	Digging	16.00 (23.57)		16.93 (24.29)		16.46 ((23.93)	
	Storage	5.33 (13.34)		10.53 (18.93)		7.93 (16.13)	
Lethpora (Pulwama)			9.64 (17.63)		10.53 (18.31)		10.08 (17.97)
	Harvesting	7.60 (16.00)		4.13 (11.72)		5.86 (43.86)	
	Digging	12.93 (19.55)		14.40 (21.30)		13.67 (20.92)	
	Storage	1.66 (7.40)		3.86 (11.33)		2.76 (9.36)	
Wattan (Pulwama)			6.01 (12.89)		6.75 (15.11)		6.09 (13.40)

Harvesting	3.46 (11.72)		2.80 (8.13)		2.73 (9.92)	
Digging	16.93 (24.29)		17.01 (24.35)		16.97 (24.32)	
Storage	5.35 (13.51)		6.66 (14.95)		6.06 (14.23)	
Pampore (Pulwama)		9.41 (17.26)		9.84 (17.77)		9.49 (17.52)
Harvesting	5.86 (14.00)		5.86 (14.00)		5.86 (14.00)	
Mean		8.08 (15.78)		9.10 (17.01)		
Digging	6.13 (14.33)		8.13 (16.56)		7.13 (15.45)	
Storage	2.80 (9.63)		4.93 (12.83)		3.86 (11.23)	
Gowharpora (Budgam)		4.17 (11.63)		6.24 (14.38)		5.20 (13.00)
Harvesting	3.60 (10.93)		5.66 (13.76)		4.63 (12.34)	
Digging	4.00 (11.53)		9.06 (17.51)		6.53 (14.52)	
Storage	1.33 (6.62)		2.93 (9.85)		2.13 (8.23)	
Kultreh (Budgam)		2.48 (8.84)		4.70 (11.91)		3.59 (10.38)
Harvesting	2.13 (8.39)		2.13 (8.39)		2.13 (8.39)	

Digging	7.20 (15.56)		12.40 (20.61)		9.80 (18.08)	
Storage	2.25 (8.64)		2.66 (9.38)		2.46 (9.01)	
Qazipora (Budgam)		3.59 (10.27)		5.46 (12.20)		4.52 (11.23)
Harvesting	1.33 (6.62)		1.33 (6.62)		1.33 (6.62)	
Digging	3.73 (11.13)		11.86 (20.14)		7.79 (15.63)	
Storage	2.13 (8.39)		2.26 (8.64)		2.19 (8.52)	
Wadipora (Budgam)		2.22 (8.21)		5.19 (11.90)		3.70 (10.06)
Harvesting	0.8 (5.13)		1.46 (6.94)		1.13 (6.03)	
Mean		3.11 (9.73)		5.40 (12.60)		
Digging	1.86 (7.83)		2.47 (9.04)		2.16 (8.44)	
Storage	1.66 (7.40)		2.30 (8.72)		1.98 (8.06)	
Sirhama (Anantnag)		1.57 (7.17)		2.05 (8.18)		1.81 (7.68)
Harvesting	1.2 (6.28)		1.4 (6.79)		1.3 (6.54)	

Digging	1.73 (7.55)		3.3 (10.46)		2.51 (9.01)	
Storage	1.87 (7.85)		2.2 (8.52)		2.03 (8.19)	
Khiram (Anantnag)		1.66 (7.40)		2.41 (8.84)		2.04 (8.12)
Harvesting	1.4 (6.79)		1.73 (7.55)		1.56 (7.17)	
Digging	1.75 (7.60)		2.13 (8.39)		1.94 (8.00)	
Storage	1.33 (6.62)		0.86 (5.32)		1.09 (5.97)	
Marhama Wadur (Anantnag)		1.40 (6.79)		1.50 (6.94)		1.45 (6.87)
Harvesting	1.13 (6.16)		1.53 (7.10)		1.33 (6.63)	
Digging	2.00 (8.13)		3.13 (10.07)		2.56 (9.1)	
Storage	1.52 (7.08)		1.4 (6.79)		1.46 (6.94)	
Sirigopora Anantnag)		1.65 (7.36)		2.06		1.86 (7.69)
Harvesting	1.43 (6.86)		1.66 (7.40)		1.54 (7.09)	
Mean		1.57 (7.18)		2.00 (8.13)		

Mean of the year		**4.25 (11.01)**		**5.5 (12.44)**	**4.9 (11.61)**	
	Digging	7.42 (14.47)		9.86 (17.37)	8.64 (15.92)	
Mean of the Stages	Storage	2.66 (9.06)		3.98 (10.90)	3.32 (9.98)	
	Harvesting	2.67 (9.05)		2.81 (9.05)	2.74 (9.15)	

	$SE_M(\pm)$	CD (P = 0.05)
Location	0.57	1.13
Stage	0.28	0.56
Year	0.23	0.46
Location x Stage	0.98	1.95
Location x Year	0.80	1.60
Stage x Year	0.40	0.10
Location x Stage x Year	1.39	2.76

Figures in parenthesis are angular transformed values.

***Intensity CV: 14.45**

Sign: Y : Year
L : Location
S : Stage

The data clearly point out that the corm rot is very serious at digging stage of the crop that is after over summering of the corms. Pooled data of corm rot incidence and intensity that occurred in the districts of Pulwama, Budgam and Anantnag during the two years of study is presented in Table-3 and Fig.4. Mean per cent incidence between three districts during two years ranged from 8.84 to 23.33 per cent, observed highest in district Pulwama followed by Budgam. Similarly mean per cent intensity between three districts ranged from 1.79 to 8.54 recorded highest at Pulwama district. These figures clearly show that district Pulwama which is traditionally saffron growing has the highest corm rot status followed by Budgam and Anantnag districts where saffron cultivation has been extended in recent past.

4.3 Symptomatology

The above ground field symptoms of corm rot disease were observed throughout the year in comparison to healthy. The data are presented in Table-4.

From the data it is clear that in case of healthy crop the flower count viz-a-viz number of corms extracted was almost equal, indicating

Table: 3 Overall status of Saffron corm rot in three districts of Kashmir valley

District	Per cent Incidence			Per cent Intensity		
	1999	2000	Mean	1999	2000	Mean
Pulwama	22.94	23.73	23.33	8.08	9.10	8.54
Budgam	10.91	12.55	11.73	3.11	5.40	4.26
Anantnag	7.60	10.07	8.84	1.57	2.00	1.79
Mean	13.82	15.45	-	4.25	5.50	-

Table 4:	Above ground symptoms of the corm rot disease observed on saffron plants in the field*.					
Saffron crop	Flower count (per m^2)	Foliage symptoms	Flowering period	Corm condition		Corm size
				Healthy	Diseased	
Healthy	500	Lush green, spotless, shiny, erect	7 weeks	495	5	3.5 – 6.5 cm
Diseased	350	Yellowish dull, tip burn, drooping	5 weeks	200	150	2-2.5 cm

*Date based on 2 years of study.

that every healthy corm gives out a single flower. The foliage were lush green with no pathological spots, shinning, erect and vigorous leaves spreading magnificently around the basal corms. The flowering period lasted for seven weeks, beginning first week of October and the reproductive phase lasted for four months. The number of diseased corms was negligible (Plate 2a).

In case of diseased corm beds, the flower count was just 350, the foliage was yellow dull, drooping with tip burn symptoms. These symptoms did not show any fungal or bacterial infection. The flowering period lasted just for 5 weeks and the flower emergence was erratic. The reproductive phase was short by one month and the dormancy phase was prolonged. The number of healthy corms was just 200 and the remaining partly or fully rotten (dry). The tunic was loose and the corm diameter in diseased was undersize (Plate 2b).

Initially the rot lesions on the corms appeared beneath the outer tunic in the form of brown to dark brown, sunken, irregular patches at any side but frequently on buds. The lesions were usually 1-2 mm deep having raised margins. As rot advanced, saffron plants manifested damping off, basal stem rot, root rot, drooping and wilting of plants. The affected corm plants generally showed discoloured foliage and foliage got detached easily, the outer tunic was observed free of any rot symptoms (Plate 3).

4.4 Isolation of the fungal flora

In all, five fungi were isolated from corm rot region of saffron. The fungi isolated were:

Fungi	Remarks
Fusarium solani (Mart.) Sacc.	Cultures deposited at ITCC, IARI, New Delhi under 5146.02; 5147.02 and 5148.02
Fusarium oxysporum Schlecht.	
Fusarium moniliforme Sheld.	
Alternaria alternata (Er.) Kessler	
Penicillium sp. Link.	

The morphological and cultural characters of the three pathogenic species isolated are described as under: (Plate 4)

	Fusarium solani	*Fusarium oxysporum*	*Fusarium moniliforme*
Growth rate	Fast	Fast	Fast
Colony character	Green to bluish brown, little aerial mycelium	White with purple tinge aerial mycelium, pigmented purple to blue.	White granulated to purple, reverse of culture colourless to purple.
Microconidia	Abundant, 0-1 septate, 8.5 – 16 x 2.50-3.60 µm, oval with thicker wall, hyaline.	Generally abundant, round 6-10 x 2.0-3.5 µm, non-septate, ellipsoidal and straight.	Rare, 5-12 x 2.5-3.4 µm, non-septate, formed in chains.
Macroconidia	Moderately curved with short blunt apical cell and pedicellate basal cell, 3 septate, 29-42 x 4-6 µ m.	Fusiform, moderately curved, pointed at both ends, basal cell pedicellate, 22-25 x 3-4 µ m.	Clavate –non-septate with flattened base, 4.5-11 x 2.3 µm. Formed in chains basal cell bearing 2-3 apical phialids.
Conidiophores	Distinct, simple, elongated, narrow slightly towards apex, later sparsely shorter branched vertically forming sporodochium.	Sparsely branched, simple terminal, hyaline smooth, 6-12 µm.	Branched.
Chlamydospores	Produced singly or in pairs in terminal, lateral or inter colony position, hyaline, smooth 6.5-10 µm.	Sparse, hyaline, smooth walled both inter calary and terminal, 7.75 x 7.31 µ m.	Absent.

4.5 Cultural studies

The data on the linear growth of three species of *Fusarium* at 24 hours interval for a period of seven days at 25 ± 2^0C is presented in Table-5 and Fig.5.

From the data it is clear that the growth had a linear increase with the passage of time with respect to all the species. The rate of growth however, varied from species to species. After 24 hours, the *F. solani* had an average colony diameter of 12.50 mm, *F. oxysporum* 13.25 and *F. moniliforme* 14.20 mm. After 144 hours it was 60 mm, 56.25 mm and 57.20 mm, respectively. The data indicate that the *F. solani* grew at a consistent speed compared to other two species that were faster at the initial stages but slow at the final stages in growth indicating the serious potential of inoculum build up with *F. solani*.

Table: 5 Average growth of different species on Richard's agar medium at 25±2^{0}C

Period (hours)	Average dia; of colony (mm)		
	Fusarium solani	*Fusarium oxysporum*	*Fusarium moniliforme*
24	12.50	13.25	14.20
48	20.00	19.25	20.00
72	30.50	28.70	27.00
96	40.75	36.45	37.00
120	50.00	51.00	52.00
144	60.00	56.25	57.20

Average of three replications.

4.6 Pathogenicity

The data on the reaction of corms towards the fungi isolated from corms is presented in Table-6 and Plate 5.

Table 6:	Response of healthy Saffron corms to fungi isolated under artificial inoculations	
Fungus		Response
Fusarium solani		+a
Fusarium oxysporum		+
Fusarium moniliforme		+
Alternaria alternate		-
Penicillium sp.		-
+ = Pathogenic	- = Non-pathogenic	a = Virulent

The data indicate that all the three species of *Fusarium* tested were pathogenic but *F. solani* was more vigorous than other two species while *Alternaria alternata* and *Penicillium* sp. failed to induce any rot symptoms. The symptoms produced by the pathogenic fungal isolates (*F. solani*) in inoculated corms of saffron were found more or less similar to those recorded in naturally infected corms. Observations on the appearance of symptoms in inoculated injured and un-injured corms

revealed that injury to corms helped in initiation of quick infection and subsequent rot development, as symptoms in these corms appeared generally 10 days after inoculation. While as in case of un-injured corms, the symptoms appeared after 20 days of inoculation. Besides, pathogen was found to be more aggressive in wounded corms as compared to those in un-injured corms. Koch's pastulates were confirmed by reisolating the pathogen from the inoculated corms and by comparing with original isolate.

4.7 Association of nematodes and *Fusarium propagules* in rhizosphere of saffron corm

Data on the population density of nematodes per unit of soil and propagules of *Fusarium* species from twelve locations of Kashmir is presented in Table-7 and Fig.6.

The data indicate that nematodes were invariably associated with *Fusarium* species in all the locations of the samples from rhizosphere, but nematode population density and spore count varied from location to location. The *Fusarium* count ranged from 3.00 to 54.34 x 10^3 g^{-1} soils with an average of 22.07 x 10^3 g^{-1} soils while nematode population varied from 100 to 1300 with an average of 619/256 cc soil. All the locations of Pulwama district had a higher nematode *Fusarium* spp.

Table 7:	Population density of nematodes (per 250 cc soil) and *Fusarium* sp. (-x $10^3 g^{-1}$ soil) in saffron rhizosphere in different districts of Kashmir

District	Location	*Fusarium* species	Mean population density of nematodes
Pulwama	1. Zaffron colony	42.00	840
	2. Lathpora	40.00	992
	3. Wattan	29.00	585
	4. Pampore	54.00	1300
Budgam	1. Gowharpora	20.00	1041
	2. Kultreh	10.75	456
	3. Wadipora	15.00	630
	4. Qazipora	19.50	818
Anantnag	1. Sirhama	10.50	192
	2. Khiram	11.25	333
	3. Murhama wudur	3.00	100
	4. Srigufwara	9.50	141
Average		22.07	619

population count as compared to the other locations of Budgam and Anantnag districts. On the other hand, Anantnag had a lower *Fusarium* spp. count and nematode population than Pulwama and Budgam. The observations further indicate that among all the locations, the *Fusarium* species and nematodes were more dominant in the soils collected from Pampore (Pulwama), the traditional saffron growing tract, than other areas.

4.7.1 Frequency of occurrence of *Fusarium* species at various stages of crop development

The data on the frequency of occurrence of three species of *Fusarium* with corms collected at digging, storage and harvesting stages of Pulwama district is presented in Table-8 (Plate.6).

The data indicate that *F. solani* was the only species available at corm digging and harvesting stages, while other two species were isolated only from the infected corms collected at storage stage, there too *F. solani* was the most predominant.

These studies clearly establish that *F. solani* is the most dominant pathogen of corm rot and the remaining two species show their appearance only in corm storage.

Table 8:	Per cent frequency of *Fusarium* species associated with corm rot of Saffron at different stages of corm collection in Pulwama during 1998

Fungi	Digging	Storage	Harvesting
Fusarium solani	100.00	39.50	100.00
Fusarium oxysporum	0.00	26.50	0.00
Fusarium moniliforme	0.00	23.00	0.00

Average of 5 replications.

4.7.2 Interaction effects of *Fusarium solani* and nematodes on corm rot and yield of saffron

The data is present in Table-9. From the date is clear that the inoculation with nematodes and pathogenic fungus either separately or simultaneously significantly affected the disease development and saffron yield. However, simultaneous inoculations with both the pathogens produced the highest diseased corms of 50.00 per cent with 14.66 per cent intensity compared to nematode alone which recorded least corm rot incidence of 26.66 per cent of 5.33 per cent intensity equally followed by fungus alone which produced 30.00 per cent diseased corms with 8.00 per cent intensity. The differences in yield in the treatments were significant when compared to check (un-inoculated). Inoculation of nematode along with fungus recorded significantly the least saffron yield (150 mg / 10 plants) as compared to other treatments. The colour of corm rot also differed between three treatments. It was pale yellow with nematode infestation, dark brown with fungus colonization and black where the combined inoculation of fungus and nematode was given.

Table 9: Interaction effect of *Fusarium solani* and nematodes on the development of corm rot and yield of saffron

Treatment	Colour of rot	Percent Disease Incidence	Percent Disease Intensity	Yield (mg)/10 plants
Nematode alone (N)	Pale yellow	26.66 (31.08)	5.33 (13.35)	176
Fungus alone (F)	Dark brown	30.00 (33.21)	8.00 (16.43)	170
Combined inoculation (N+F)	Black	50.00 (45.00)	14.66 (22.51)	150
Un-inoculated check		0.00 (0.00)	0.00 (0.00)	200
(Figures in parenthesis are angular transformed values).				
CD (P=0.05)		(6.08)	(5.46)	18.50

4.8 Management studies

4.8.1 Management through organic amendments

4.8.1.1 Effect of organic amendments on total fungal population of soil

The data on the effect of five organic amendments on the fungal population recorded at 30 days interval for a period of 90 days is presented in Table-10.

Perusal of the data indicate that the mean population count of fungal propagules increased significantly with the passage of time with respect to all the organic amendments tried. Generally the increase in fungal population was slow but steady after 30 days in all the treatments. Among the amendments, FYM with a population count of 35.08 x $10^4 g^{-1}$ soil was most effective in supporting the maximum fungal population at dosage ratio of 4:1 (soil: amendment). This was followed by poultry manure (4:1 w/w), FYM (5:1 w/w) and mushroom compost (5:1 w/w) recording fungal population of 33.17, 32.92 and 32.75 x $10^4 g^{-1}$ soil, respectively. All these treatments exhibited non-significant difference among themselves. The other organic amendment treatments like poultry manure and mushroom compost each at the doze rate of 5:1 w/w also significantly promoted the total fungal population over non-amended

Table 10: Effect of different organic amendments on total fungal population in saffron soils during 2000

Amendment	Ratio (S:A)	Number of propagules (10^4 g^{-1} soil) at days after treatment			
		30	60	90	Mean
(1)	(2)	(3)	(4)	(5)	(6)
FYM	4:1	30.00 (3.43)	36.50 (3.62)	38.75 (3.69)	35.08 (3.58)
	5:1	27.75 (3.36)	33.50 (3.54)	37.50 (3.65)	32.92 (3.52)
Poultry manure	4:1	28.50 (3.39)	35.00 3.58)	36.00 (3.60)	33.17 (3.53)
	5:1	27.50 (3.35)	33.25 (3.54)	35.25 (3.59)	32.00 (3.49)
Mushroom compost	4:1	27.75 (3.36)	34.75 (3.58)	35.75 (3.61)	32.75 (3.52)
	5:1	26.50 (3.32)	34.00 (3.55)	34.75 (3.58)	31.75 (3.48)
Saw dust	4:1	16.00 (2.83)	18.75 (2.93)	19.50 (3.02)	18.08 (2.92)
	5:1	15.75 (2.80)	17.50 (2.90)	18.00 (2.94)	17.08 (2.88)

(1)	(2)	(3)	(4)	(5)	(6)
Spent Mushroom	4:1	16.25 (2.85)	18.00 2.94)	19.25 (2.99)	17.83 (2.94)
	5:1	16.00 (2.83)	17.25 (2.90)	18.75 (2.93)	17.33 (2.89)
Control (no amendment)		16.00 (2.83)	18.50 (2.96)	20.25 (3.05)	18.25 (2.94
	Overall Mean	**21.99 (3.10)**	**26.29 (3.259**	**27.76 (3.39)**	**25.23 (3.24)**

Figures in parenthesis are logarithmic transformed values for propagules.

CD (P=0.05) Amendment (A) = (0.03) Intervals (I) = (0.04) A x I = (0.02)

S = Soil A = Amendment

*Mean of five replications; initial inoculum 15 x 10^4 g^{-1} soil.

soil. Saw dust and spent mushroom compost amended soils at both the tested concentrations recorded the least fungal population as compared to all other treatments of organic amendments. The overall mean count in these treatments was 17.08 to 18.08 and 17.33 to 17.83 x $10^{-4}g^{-1}$ soil, respectively, whereas fungal population recovered from non-amended soil was 18.25 x $10^{4}g^{-1}$ soil. These observations suggest that no propagule count increased over check in all the combinations of soil + saw dust and soil + spent mushroom compost. However, the interaction between amendments and intervals collectively and individually was observed statistically significant. Decomposition of composts for 90 days significantly increased the fungal population.

4.8.1.2 Effect of amendments on soil population of *Fusarium solani*

The data on the population count of pathogenic fungus (*F. solani*) in the soil that received different organic amendments is presented in Table-11.

The data indicate that *Fusarium solani* count per unit of soil with respect to all the organic amendments decreased with the passage of time when compared to non-amended check. All the amendments reduced the *Fusarium solani* population in the soil significantly, the reduction

Table 11: Effect of different organic amendments in soil on population of *Fusarium solani* during 2000

Amendment / Treatment	Ratio (S:A)	**Number of propagules (x 10^4 g^{-1} soil) at days after amendments**						
		30 days	**Reduc. over control**	**60 days**	**Reduc. over control**	**90 days**	**Reduc. over control**	**Mean**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
FYM	4:1	24.50 (3.24)	41.31	27.75 (3.36)	40.95	30.00 (3.43)	46.66	27.42 (3.34)
	5:1	28.50 (3.38)	31.73	32.00 (3.50)	31.91	33.50 (3.54)	40.44	31.33 (3.47)
Poultry manure	4:1	25.25 (3.27)	39.52	29.75 (3.42)	36.70	30.50 (3.45)	45.77	28.50 (3.38)
	5:1	28.25 (3.38)	32.33	34.25 (3.56)	27.12	36.50 (3.62)	35.11	33.00 (3.52)
Mushroom compost	4:1	30.00 (3.43)	28.14	34.75 (3.58)	26.00	36.50 (3.62)	35.11	33.75 (3.54)
	5:1	33.50 (3.54)	19.76	36.50 (3.62)	22.34	39.50 (3.70)	29.77	36.50 (3.62)
Saw dust	4:1	35.50 (3.60)	14.87	38.25 (3.67)	18.61	39.75 3.71)	29.33	37.83 3.66)
	5:1	38.00 (3.68)	8.98	39.00 (3.70)	17.02	40.50 (3.73)	28.00	39.17 (3.70)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Spent Compost Mushroom	4:1	35.75 (3.61)	14.37	38.75 (3.68)	17.65	40.00 (3.71)	28.88	38.17 (3.67)
	5:1	38.50 (3.68)	7.78	40.00 (3.71)	14.89	41.75 (3.75)	25.77	40.09 (3.71)
Control		41.75 (3.75)	-	47.00 (3.87)	-	56.25 (4.06)	-	48.33 (3.89)
Overall Mean		**33.43 (3.52)**		**37.12 (3.65)**		**40.08 (3.71)**		**36.87 (3.62)**

Figures in parenthesis are logarithmic transformed values for propagules

CD(P=0.05) Amendment (A) = (0.03) Intervals (I) = (0.03) A x I = (0.05)

*Mean of three replications; initial inoculum 4 x 10^4 g^{-1} soil.

ranging between 17.0 and 43.3 per cent over control. Among the amendments, FYM was found most effective in reducing the inoculum load of test fungus to a level of 27.42 x 10^3g^{-1} from 48.33 x 10^3g^{-1} in un-amended check, thereby registering a reduction of 43.3 per cent at 4:1 w/w dosage. At this dosage level i.e. 4:1 w/w, poultry manure proved to be next best amendment in reducing the inoculum to a level of 28.5 x10^3g^{-1} from 48.33 x 10^3g^{-1} soil in control thereby recording a reduction of 41.0 per cent over control. FYM at 5:1 dosages ranked third in the order of efficacy by registering a reduction of about 35.2 per cent over control in the inoculum load of test pathogen. Poultry manure (5:1 ratio) and mushroom compost (4:1 ratio) were statistically at par with regard to their efficacy in reducing the population of corm rot pathogen. Saw dust and spent mushroom amendments were found to be least effective but still caused appreciable reduction in pathogen propagules, reduction ranging between 17.00 and 21.72 per cent, over non-amended check. These observations clearly indicate the superiority of FYM and poultry manure over rest of the amendments tried. Results also suggest that decomposition of amendments in soil for longer periods (90 days) was more appropriate for bringing down

the viable propagules of the pathogen in the soil. In general suppression effect increased with the amount of organic amendment added to the soil.

4.8.1.3 Effect of organic amendments on corm rot and saffron yield during 2000

Five organic amendments were evaluated each at two dosage levels to determine their effect on corm rot development and saffron yield. The data reveals (Table-12) that in general all organic amendments considerably reduced the incidence and intensity of corm rot with a concomitant increase in saffron yield. Amendments brought down the rot incidence from 50.00 per cent in the non-amended check to 23.33 – 40.00 per cent in treated ones. Similarly, disease intensity was reduced from 29.33 per cent in control treatment to 8.00 - 26.00 per cent in amended treatments and the saffron yield was enhanced by 10.00-75.00 per cent in amended soils over control achieved maximum in FYM amendment at higher dosage (4:1 w/w) and least in saw dust amended soils at low dosage (5:1 w/w). Among the amendments, comparatively least corm rot incidence and intensity (23.33 and 8.00 per cent, respectively) and highest saffron yield (350 mg/10 plants) was recorded in treatments amended with FYM (4:1 w/w). This was followed by poultry manure amendment, at the same dosage, recording disease incidence of 26.66 per cent,

Table: 12 Effect of different organic amendments on the incidence and intensity of corm rot and fresh stigma yield of saffron during 2000

Amendment	Corm rot incidence, soil: amendment ratio (w/w)			Corm rot intensity, soil: amendment ratio (w/w)			Yield/10 plants of fresh stigmas (mg), soil: amendment ratio (w/w)		
	4:1	5:1	Mean	4:1	5:1	Mean	4:1	5:1	Mean
Decomposed FYM	23.33 (28.88)	30.00 (33.21)	26.67 (31.05)	8.00 (16.42)	9.33 (17.79)	8.67 (17.11)	350	310	330
Poultry manure	26.66 (31.08)	30.00 (33.21)	28.33 (32.15)	10.00 (18.43)	13.33 (21.41)	11.67 (19.92)	330	300	315
Mushroom compost	30.00 (33.21)	36.66 (37.27)	33.33 (35.24)	14.00 (21.97)	14.66 (22.51)	14.33 (22.24)	325	290	307.5
Spent mushroom compost	33.66 (35.26)	40.00 (39.23)	36.83 (37.25)	20.33 (26.80)	23.66 (29.10)	22.00 (27.95)	275	260	267.5
Saw dust	36.66 (37.27)	40.00 (39.23)	38.33 (38.25)	22.66 (28.42)	26.00 (30.66)	24.33 (29.54)	224	220	222
Control check	50.00 (45.00)	50.00 (45.00)	50.00 (45.00)	29.33 (32.37)	29.33 (32.37)	29.33 (32.37)	200	200	200
Mean	**33.39 (35.11)**	**37.78 (37.85)**		**17.28 (24.06)**	**19.38 (25.80)**		**284**	**263.33**	

Figures in parenthesis are angular transformed values.

CD (P = 0.05)	Incidence	Intensity	Yield
Amendment (A)	(1.11)	(1.42)	19.17
Ratio (R)	(0.90)	(1.35)	11.38
Interaction A x R	(2.25)	(2.41)	27.88

intensity of 10.00 per cent and saffron yield of 330 mg/10 plants as against 50.00 and 29.33 per cent and 200 mg/10 plants, respectively, in non-amended check.

Corm rot development was also best contained by mushroom compost amendment as compared to saw dust and spent mushroom compost. The various amendments, depending on their efficacy in reducing per cent disease incidence and intensity besides enhancing saffron yield can be placed in the following descending order, FYM poultry manure, mushroom compost, spent mushroom compost and saw dust. Highest dosages of all organic amendments exhibited better disease controlling potentially resulting in higher crop yield. When all the dosages of different organic amendments are viewed together, the mean reduction in disease incidence and intensity and increase in saffron yield was maximum (46.66, 70.43 and 65 per cent, respectively) in FYM amendment and minimum in saw dust (23.34, 17.04 and 11.00 per cent, respectively) followed by spent mushroom compost with significant differences among themselves.

4.8.1.4 Effect of organic amendments on corm rot and saffron yield during 2001

The observations with regard to the corm rot intensity and saffron yield as influenced by amending the soil with organic amendments were recorded in succeeding year i.e. 2001. The data generated is presented in the Table-13. The results reveal that the amendments show more or less similar trend as in previous year (2000) with regard to their potential in reducing the corm rot disease thereby enhancing the yield to appreciable levels as compared to un-amended check. The data clearly indicates that organic amendments exhibited higher disease controlling potential resulting in appreciable higher saffron yield, during 2001 as compared to 2000. This can be viewed from this fact that all the organic amendments reduced the disease incidence by 26.32 - 55.26 per cent and disease severity by 24.17 – 74.18 per cent over control during 2001. While as the corresponding decrease during 2000 was 23.34 – 46.66 per cent and 17.04 – 70.43 per cent, respectively. Average yield enhancement over check due to incorporation of amendments was also much higher (ranged between 17.00 to 79.00 per cent) during 2001 as compared to 2000 where it ranged between 11.00 to 65.00 per cent. Again during 2001, among the tested amendments maximum disease reduction and increased saffron yield

Table: 13 Effect of different organic amendments on the incidence and intensity of corm rot and fresh stigma yield of saffron during 2001

Amendment	Corm rot incidence soil: amendment ration (w/w)			Corm rot intensity soil: amendment ration (w/w)			Yield/10 plants of fresh stigmas (mg) soil: amendment ration (w/w)		
	4:1	5:1	Mean	4:1	5:1	Mean	4:1	5:1	Mean
Decomposed FYM	26.66 (31.08)	30.00 (33.21)	28.33 (32.15)	9.33 (17.79)	11.38 (19.66)	10.33 (18.72)	380	375	377.5
Poultry manure	30.00 (33.21)	33.33 (33.83)	31.66 (35.52)	11.33 (19.66)	13.33 (21.41)	12.33 (20.54)	372	365	368.5
Mushroom compost	36.66 (37.26)	40.00 (39.23)	38.33 (38.25)	15.66 (23.35)	17.66 (24.84)	16.66 (24.08)	340	330	335
Spent mushroom compost	43.33 (41.16)	46.66 (43.08)	45.00 (42.10)	22.66 (28.42)	24.00 (29.33)	23.33 (28.88)	310	305	307.5
Saw dust	46.66 (43.08)	46.66 (43.08)	46.66 (43.08)	26.00 (30.66)	31.00 (34.83)	30.33 (33.41)	260	255	257.5
Control check	63.33 (53.73)	63.33 (53.73)	63.33 (53.73)	40.00 (39.23)	40.00 (39.23)	40.00 (39.23)	210	210	210
Mean	**41.10 (39.92)**	**43.33 (41.02)**		**20.83 (26.51)**	**22.88 (28.22)**		**312.00**	**306.66**	

Figures in parenthesis are angular transformed values

CD (P = 0.05)	Incidence	Intensity	Yield
Amendment (A)	(1.11)	(1.25)	20.75
Ratio (R)	(0.80)	(1.10)	11.98
Interaction A x R	(2.47)	(2.87)	29.34

were recorded with FYM amendment followed by poultry manure and mushroom compost amendments. Spent mushroom compost and saw dust found comparatively less effective.

4.9 Biological control of corm rot

4.9.1 Antagonistic effect of bioagents against *Fusarium solani*

The data recorded on the mycelial growth inhibition of *Fusarium solani* by four antagonists is shown Table-14.

From the data it is clear that all the four bioagents were successful in inhibiting the growth of *Fusarium solani* to a considerable extent. All the bioagents differed significantly with regard to their potentiality in inhibiting the growth of *F. solani.* The inhibition was significantly highest (55.87 per cent) with *Trichoderma viride* followed by *Gliocladium virens* (46.30 per cent) and *Trichoderma harzianum* (42.38 per cent).The least inhibition was with *Aspergillus niger* (32.20 per cent).

4.9.2 Inhibition of *Fusarium solani* by bioagents on the basis of volatility

Inhibition of mycelial growth by bioagents as a result of their volatile and non-volatile activity was carried through two different laboratory experiments and the results are presented in Table-15.

Table: 14 *In vitro* assay of fungal antagonists against *Fusarium solani*

Fungal antagonists	Mycelial growth (mm)	Growth inhibition over control (%)
Trichoderma viride	39.72 (39.06)	55.87
Trichoderma harzianum	51.86 (46.06)	42.38
Gliocladium virens	48.34 (44.04)	46.30
Aspergillus niger	61.00 (51.35)	32.20
Control	90.00 (71.56)	-

Figures in parenthesis are angular transformed values.

C.D (P = 0.05): (2.23)

Table: 15 Inhibition of mycelial growth of *Fusarium solani* by volatile and non-volatile inhibitors by different antagonists

Fungal antagonists	Average mycelial growth inhibition	
	Volatile inhibitors**	Non-volatile inhibitors***
Trichoderma viride	42.30 (40.57)	30.00 (33.21)
Trichoderma harzianum	29.40 (32.83)	25.40 (30.26)
Gliocladium virens	27.50 (31.62)	22.60 (28.38)
Aspergillus niger	23.70 (29.12)	20.20 (26.7)

Figures in parenthesis are angular transformed values.

CD (P = 0.05) (1.24) (1.28)

** By six day old culture of antagonists.

*** By 10 days old culture filtrate of antagonists.

The data with respect to mycelial growth inhibition on account of volatile activity indicate that all the bioagents do possess the volatile mechanism. The growth inhibition of pathogen significantly varied with the tested antagonist, recorded highest inhibition with *T. viride* (42.30 per cent) followed by *Trichoderma harzianum* which caused inhibition of 29.4 per cent.

The inhibition due to non-volatile activity was also exhibited by all the four bioagents. The differences in growth inhibition of the pathogen were significant with the bioagents tested. Highest inhibition of 30.00 per cent was with *Trichoderma viride* treatment followed by *Trichoderma harzianum* (25.40 per cent) and least in *Aspergillus niger* treatment (20.20 per cent). The data indicate that bioagents employ both volatile and non-volatile inhibitory process against test fungal pathogen.

4.9.3 Evaluation of antagonists against corm rot severity in polybags

The data on the effect of few antagonists on disease severity is presented in Table-16 (Plate 7). The data indicate that the disease intensity was also considerably reduced by the incorporation of bioagents. Among the bioagents, *Trichoderma viride* treatment recorded the least disease severity of 13.33 per cent followed by *Gliocladium virens* which

Table 16: *In vivo* efficacy of different antagonists against corm rot of saffron

Treatments	Disease intensity (%)
Trichoderma viride	13.33 (21.41)
Trichoderma harzianum	20.00 (26.39)
Gliocladium virens	15.33 (23.05)
Aspergillus niger	22.00 (27.97)
Control	27.33 (31.51)
Figures in parenthesis are angular transformed.	
CD (P= 0.05)	2.69

recorded 15.33 per cent disease severity as against the control treatment where it was 27.33 per cent. The data established the utility of bioagents in managing the corm rot severity due to *Fusarium solani.*

4.10 Role of soil solarization in managing saffron corm rot

4.10.1 Effect of solarization on soil temperature

Effect of soil solarization on soil temperature at various depths and durations is presented in Table-17. Average of soil temperature at 5 and 10 cm depths over different periods of solarization indicated variation. Soil solarization for 6 weeks during mid June to July increased the soil temperature at 5 cm depth by 8.4 and 8.9^{0}C during 2000 and 2001, respectively. The maximum soil temperature recorded at 5 cm depth during the two years was 42.5 and 43.8^{0}C after 6 weeks solarization and 34.1 and 34.9^{0}C during the corresponding period in non-solarized treatments. While after 4 weeks of solarization, the maximum temperature recorded during two years was 39.3 and 40.0^{0}C and during the corresponding period a temperature of 32.8 and 33.6^{0}C was recorded in non-solarized soil thereby showing increase in the temperature to the extent of 6.5 and 6.4^{0}C. The rise in temperature during both the years was more at 5 cm depth as compared to 10 cm depth. These observations

Table: 17 Effect of soil solarization on soil temperature during 2000 and 2001

Treatment	Duration (weeks)	Depth. (cm)	Average soil temperature (^{0}C)	
			2000	2001
Solarized	6	5	42.5	43.8
		10	35.1	36.2
	4	5	39.3	40.00
		10	34.1	36.4
Non-solarized	6	5	34.1	34.9
		10	29.0	29.5
	4	5	32.8	33.6
		10	27.2	26.7

clearly indicate that soil solarization helps in raising the soil temperature at five centimeter depth which harbours large number of micro-organisms in the rhizosphere of saffron and provides detrimental conditions for their multiplication and survival and thus is possibly a viable method of disease management.

4.10.2 Effect of solarization on disease incidence during 2000 and 2001

Effect of soil solarization in combination with FYM and irrigation separately as well as jointly on disease incidence of corm rot of saffron is shown in the Table-18.

Data indicate that solarization considerably suppressed the corm rot disease during both the years of experimentation. Solarization after 4 and 6 weeks resulted in significant reduction of corm rot incidence by 47.9 per cent and 52.2 per cent during 2000 and 34.7 per cent and 41.4 per cent in 2001, respectively over non-solarized check. Among the solarized treatments, highest reduction in disease was recorded in 6 weeks of solarization after amending the soil with FYM and irrigation. Disease incidence in this treatment was 10.00 per cent and 20.00 per cent in the two successive years compared to 40.0 and 60.0 per cent in non-solarized treatment. This was followed by 6 weeks solarization after

Table: 18 Effect of soil solarization on the incidence of saffron corm rot

Treatment	2000			2001		
	Disease incidence (%)		Mean	Disease incidence (%)		Mean
	Weeks of solarization			Weeks of solarization		
	4	6		4	6	
Solarization alone	33.66 (37.26)	30.00 (33.21)	33.33 (35.24)	50.00 (45.00)	46.66 (43.08)	48.33 (44.04)
Solarization after irrigation	23.33 (28.88)	23.00 (26.56)	21.66 (27.22)	46.66 (43.08)	43.33 (41.16)	45.00 (42.12)
Solarization after application of FYM	13.33 (21.41)	13.33 (21.41)	13.33 (21.41)	33.33 (35.26)	30.66 (31.62)	31.99 (34.44)
Solarization after application of FYM & irrigation	13.33 (21.41)	10.00 (18.43)	11.66 (19.92)	26.66 (31.08)	20.00 (26.56)	23.33 (28.82)
Control (no solarization)	40.00 (39.23)	40.00 (39.23)	40.00 (39.23)	60.00 (50.76)	60.00 (50.26)	60.00 (50.76)
Mean	**25.33 (29.64)**	**22.66 (27.77)**		**43.33 (41.03)**	**40.13 (39.03)**	

Figures in parenthesis are angular transformed values.

CD (P = 0.05)		
Weeks	(1.22)	(1.20)
Treatments	(1.24)	(1.86)
Treatments x weeks	(2.38)	(2.79)

application of FYM which recorded incidence of 13.33 per cent during 2000 and 30.66 per cent in 2001. Appreciable disease reduction of 42.5 per cent and 27.78 per cent in successive years, respectively, over control, was recorded in solarization after application of irrigation to plots. Solarization without any amendments proved comparatively less effective but still checked the infestation over check to the extent of 25 per cent during 2000 and 22.2 per cent during 2001. The data is indicative that 6 weeks solarization is more effective than 4 weeks solarization.

4.10.3 Effect of solarization in disease intensity during 2000 and 2001

Effect of soil solarization in combination with FYM and irrigation separately as well as jointly on corm rot intensity is presented in Table-19.

From the data it is evident that soil solarization also considerably reduced the severity of corm rot when compared to non-solarized treatment. The pattern of disease suppression in solarized treatments was more or less similar as observed with regard to disease incidence. In general, a progressive but significant decrease in disease severity was evident with the increase in duration of solarization in all the treatments

Table: 19 Effect of soil solarization on the intensity of saffron corm rot

Treatment	2000			2001		
	Disease intensity (%) Weeks of solarization		Mean	Disease intensity (%) Weeks of solarization		Mean
	4	6		4	6	
Solarization alone	21.33 (27.50)	20.00 (26.56)	20.66 (27.03)	25.00 (30.00)	24.33 (29.55)	24.67 (29.78)
Solarization after irrigation	18.66 (25.59)	16.00 (23.57)	17.33 (24.58)	22.66 (28.42)	21.00 (27.27)	21.83 (27.85)
Solarization after application of FYM	9.66 (18.10)	8.33 (16.77)	9.00 (17.44)	16.66 (24.08)	14.00 (21.97)	15.33 (23.03)
Solarization after application of FYM & irrigation	6.00 (14.17)	5.33 (13.34)	5.67 (13.76)	12.66 (20.84)	11.00 (19.37)	11.83 (20.11)
Control (no solarization)	27.33 (31.51)	27.33 (31.50)	27.33 (31.51)	35.33 (36.46)	35.33 (36.46)	35.33 (36.46)
Mean	**16.60 (23.37)**	**15.40 (22.35)**		**22.46 (27.96)**	**21.13 (26.70)**	

Figures in parenthesis are angular transformed values.

CD (P = 0.05)		
Weeks	(1.38)	(1.36)
Treatments	(1.86)	(1.41)
Treatments x weeks	(2.62)	(2.40)

during both the years. In other words, the reduction in disease severity was maximum (ranging between 26.8 and 80.5 per cent during 2000 and 31.2 and 68.9 per cent during 2001) with 6 weeks solarization as compared to 4 weeks solarization which gave disease reduction to the magnitude of 21.9 to 78.1 per cent and 29.3 to 64.2 per cent during two successive years, respectively, in various solarized treatments. 6 weeks solarization after application of FYM and irrigation treatment was found most effective as disease intensity in this treatment was 5.33 and 11.00 per cent in two successive years compared to 27.33 and 35.33 per cent, respectively in non-solarized treatments. The other treatments i.e. solarized irrigated and solarized amended with FYM also resulted in significant suppression of the corm rot disease severity by exhibiting disease reduction, over control of 41.45 and 69.52 per cent during 2000, and 40.56 and 60.37 per cent during 2001, respectively.

In general, the difference between various treatments and duration of solarization including their interaction were significant. The observations further reveal that soil solarization alone is not enough in managing the corm rot in saffron but application of FYM and irrigation in combination with soil solarization is more beneficial.

CHAPTER-V

DISCUSSION

Among the most important problems of saffron, corm rot has been causing a lot of concern both to the saffron growers and also the administration for the last three decades now. The single problem has been challenging the very existence of saffron which the State has name and fame. The industry has an overall turn over of forty three crores annually and a sizeable population is

directly or indirectly involved in this trade. Saffron is the identity of Pampore area and which has been mentioned in most of our ancient texts and history books. The annual yield has been falling year after year even if the area under saffron is being extended to newer areas throughout the karewa areas of Kashmir valley. Knowledge about the cause and management of corm rot is at present scanty. A few references in the literature have been scanned that indicate the isolation of some fungi from saffron corms (Dhar, 1992; Sud, *et al.*, 1999, Thakur, *et al.*, 1992).

The occurrence of fungi from corm rot by above workers is inconsistent, however, the involvement of *Fusarium* spp. has been indicated (Dhar, 1992; Sud, *et al.*, 1999). The work done so far by some workers from Kashmir has been scanty in their approach. The details about the incidence and intensity, time of appearance, causal organisms involved and method of management has not been adequately reported.

During present investigations three important parameters were identified and various experiments conducted so as to provide answer to the prevalent problem.

First of all it was thought proper to know the status of corm rot in the saffron fields of Kashmir valley in terms of incidence and intensity. The studies were conducted during 1999 and 2000. Thirty six fields from twelve locations of all the three important districts of Kashmir valley were surveyed for understanding the corm rot status at three important stages of crop growth. The corm rot incidence ranged from 4 to 42 per cent during both the years. The disease incidence varied from place to place and stage to stage. It was highest at digging stage (22.11 per cent) and lowest at harvesting stage (10.51 per cent). Dhar (1992) had conducted similar surveys in Pampore area and the incidence recorded was 6.70 to 15.20 per cent during 1988. During present studies, it was 22.94 per cent in the year 1999 and 23.73 per cent in 2000 in Pampore belt. These two surveys clearly establish that corm rot in saffron is increasing year after year. Present data confirms the occurrence of corm rot and its severe incidence in Kashmir valley. Present studies are wide based and provide the confirmation about the disease status in all the important saffron growing areas of Kashmir valley.

Measurement of disease intensity within the affected corms was attempted during present studies. The intensity ranged from 0.80 to 16.93 per cent during

1999 and 1.33 to 17.46 per cent during 2000. The intensity figures point out towards the total loss of corms due to rot, thereby indicating the loss of propagating material and yield. The pooled data for two years about incidence and intensity also point out the same phenomena. So far no report about the rot intensity measurements of corms is available from all the important saffron growing areas. These observations therefore, provide a sound base for planning the future management strategy at divisional level.

The disease syndrome in field under natural conditions has been studied and described in comparison to healthy crop. The studies revealed that the flower count per unit area along with the corm size and count gets lowered in affected crop when compared to healthy. The foliage of infected corms in the field is seen as dull, yellowish, drooping with tips burning and the flower period lasts for five weeks as against seven weeks in case of healthy. The reproductive phase was short by one month and dormancy phase prolonged in infected corms. The affected foliage did not yield any fungus. These observations have been documented for the first time and there is no other report available in the literature for any comparison. The symptoms on affected corms have been described in detail and are in agreement with the observations of Thakur (1997).

The infected corms yielded five fungi namely *Fusarium solani*, *Fusarium oxysporum*, *Fusarium moniliforme*, *Alternaria alternata* and *Penicillium* spp. The fungi were brought to pure culture, identity got confirmed and the cultures deposited with I.T.C.C., IARI, New Delhi. These fungi were studied for their pathological and morphological characters on the basis of which their identity was established. Three *Fusarium* species identified as pathogenic were studied for their growth in Richard's agar medium at 25 ± 2^0C. The three species varied for their growth. *Fusarium solani* grew at consistent speed compared to other two species and after 144 hours gave maximum growth of 60 mm indicating the serious potential of the inoculum build up when compared to other species. Such studies had also been earlier conducted with other isolates of the same fungi on same crop or in different crops and media (Cappelli, 1994; Dhar, 1992; Carta, *et al.*, 1982; Agarwal and Sarbhoy, 1978; Dharamveer *et al.*, 2002). The observations recorded are in accordance with the above workers.

The pathogenicity tests with the fungi isolated were conducted adopting Koch's postulates. All the *Fusarium* spp. were pathogenic in response under artificial inoculation while, *Alternaria alternata* and *Penicillium* spp. were non-pathogenic. Amongst the three *Fusarium* species, *Fusarium solani* was found

most virulent. Pathogenicity tests further indicated that the pathogen proved highly virulent on injured corms compared to non-injured ones. *Fusarium solani* has also earlier been reported to be the cause of corm rot of saffron from Himachal Pradesh. (Sud, *et al.,* 1999) and the present investigations are in conformity. However, Thakur, *et al.*1992 has reported *Macrophomina phaseolina* from Kishtwar (J&K) but this pathogen was not isolated from the corms collected from Kashmir. It is possible that the corm rot that prevails in Kishtwar is different than the corm rot of Kashmir valley.

Three species of *Fusarium* were isolated from rotten corms collected during corm digging, storage and saffron harvesting. The outcome of isolations revealed that *Fusarium solani* was found associated with rotten corms collected at digging, harvesting and storage stages and other two species such as *F. oxysporum* and *F. moniliforme* were observed only in corms collected from storage. This phenomenon clearly establishes the dominant prevalence of *Fusarium solani* and appears to be the major cause.

Association of nematodes and *Fusarium* propagules in the rhizosphere of saffron corms was invariably encountered from all the test locations. The *Fusarium* count ranged from 3.00 - 54.33 x $10^3 g^{-1}$ soil and nematode population

from 100 - 1300. The pathogen count varied from district to district recorded maximum in Pulwama district. Occurrence of *Fusarium* spp. and nematodes jointly in the rhizosphere indicates the complimentary nature of the eco-system. This type of association between nematodes and fungi in saffron rhizosphere has been studied for the first time. However, other workers under NATP project on saffron have also made similar observations (Zargar personal communication). The variations in population levels of nematodes and *Fusarium* spp. appears to be due to cumulative effects of various ecological and environmental factors influencing the interaction effects, their survival and multiplication (Rao and Krishnapa, 1996). Further studies with respect to nematode species involved and their potential in causing injury to corm epidermis and disease development would be beneficial.

Role of *Fusarium solani* and nematodes on the development of corm rot and yield was studied. The data established that effect of joint invasion of nematode and fungi was more pronounced than individual applications, as simultaneous inoculation of *Fusarium solani* and nematode gave highest number of rotten corms with a high disease severity and yield was the lowest compared to other treatments. The difference between treatment combinations was

significant. These studies have been attempted for the first time on this crop and there is no published data available in this aspect. High corm rot severity in combined infections may be due to synergistic relationship between the two pathogens. According to Zaki and Mantoo (2001) it is possible that nematodes in the corm rhizosphere proved beneficial for the development and colonization of *Fusarium* spp. by causing injury in the corm epidermis facilitating their entry into the corms, thus predisposing corms for the development of rot disease by fungal pathogens.

The management of saffron corm rot was attempted by adopting three approaches which are non-hazardous and eco-friendly. Effect of commonly available organic amendments (FYM, poultry manure, mushroom compost, spent mushroom compost and saw dust) on total fungal population in the rhizosphere, studied for three months at 30 days interval indicated that the total fungal propagules increased with the period of decomposition especially of FYM, poultry manure and mushroom compost. The amendments helped in building up the inoculum potential of competitive micro-organisms in the rhizosphere which in turn had deleterious effect on pathogenic *Fusaria.* Such phenomenon with the addition of organic amendments in soil are of common observation (Sharma and

Sharma, 2002; Singh and Singh, 1982; Jordan, *et al.*, 1972) and these observations are in confirmation with the above workers as far as saffron rhizosphere is concerned. The propagules count of *Fusarium solani* from the soil that received organic amendments reveal that FYM, poultry manure and mushroom compost (4:1 ratio) application considerably reduced the viable propagules of *Fusarium solani.* The decrease was maximum after 90 days. These observations establish the antagonistic affect of rhizosphere microflora upon *Fusarium solani* when amended with organic source. These studies provide a viable clue for effective management of saffron corm rot. The organic amendments besides increasing the antagonistic microbial count in the rhizosphere shall also provide enough nutrition to the developing corms and also improve the soil texture and would naturally help in corm development, multiplication and yield. Present observations get further support from the findings of several workers who worked on other isolates of *Fusarium* infecting other crops. Raj and Kapoor (1997) was of the view that antagonists which compete for the nutrients with soil borne pathogens might affect multiplication of these pathogens adversely resulting low build up of pathogens in compost amended soils Gilbert, *et al.* (1968) opined that rise in population of soil microflora ultimately suppresses growth of pathogenic forms. The incidence of

corm rot and yield after the addition of organic amendments was studied. It was found that decomposed FYM is most efficient followed by poultry manure and mushroom compost at 4:1 ratio. The disease incidence and severity was reduced to significant levels and the yield proportionally increased in these amendments. These studies clearly establish the utility of these organic amendments in disease management. Such studies on this crop have not been conducted or reported elsewhere. However, the organic amendments have successfully been used for the field control of fusarial diseases of tomato (Raj and Kapoor, 1997) muskmelon (Chakraborti and Sen, 1991). In Taiwan, many plant diseases caused by *Fusarium* spp. were effectively controlled by using composts and mineral mixture (Sun and Huang, 1985).

All the isolates of antagonists in dual culture inhibited the mycelial growth of the pathogen but *Trichoderma viride* inhibited maximum mycelial growth followed by the *Gliocladium virens* and *T. harzianum. Aspergillus niger* showed the moderate antagonism. The mechanism of inhibition may be competition for food and space, production of antibiotics and mycoparasitism (Roy, 1977). Mukherjee and Tripathi, (2000), Pandey and Upadhyay (2000), and Kumar and Dubey (2001) also observed high degree potential of these antagonists against

pathogenic *Fusarium* spp. associated with other crop plants, under *in vitro* conditions.

Mechanism of inhibition by antagonists in terms of volatility and non-volatility was also studied. The antagonists inhibited the growth of the pathogen by the production of volatile and non-volatile antifungal substances and among the bioagents maximum growth inhibition of the pathogen was shown by *T. viride* followed by *T. harzianum* and *G. virens.* Differences in inhibition per cent may be due to differences in quantity and quality of the inhibitory volatile and non-volatile substances produced by the antagonist. *Trichoderma* spp. an antagonistic to a range of fungi reported to be producing volatile and non-volatile antibiotics (Dennis and Webster, 1971(a), 1971 (b), Mukhopadhyay and Kaur, 1998).

These observations establish that in rhizosphere both these phenomenon must be operating that results in the decrease of pathogenic *Fusarium solani* thereby reducing the corm rot development. As when these bioagents tested *in vitro* (in polybags), all the bioagents reduced the corm rot severity significantly as compared to check. *T. viride* was found to be the best with lowest severity

(13.37%) followed by *G. virens* (15.32%). Thakur (1997) also reported the potential of these bio-control agents in the management of corm rot of saffron.

Soil solarization having come up as a latest technique in managing soil borne diseases in many crops. This concept was applied for managing the corm rot of saffron during the present studies. The studies clearly establish that solarization effectively increased the temperature at all depths but the rise was more at 5 cm depth as compared to 10 cm depth during both the years. Solarization for 6 weeks duration recorded the maximum rise in temperature during both the years at 5 cm depth (8.4^0C and 8.9^0C, respectively). Kumar and Sood (2001) recorded the temperature profiles at different depth and found maximum increase of temperature at 5 cm depth after 8 to 10 weeks. Solarization temperature rises under polythene cover have also been recorded by many other workers (Chellemi, *et al.*, 1994; Raj, *et al.*, 1997). The corm rot incidence and intensity was assessed with solarization as an individual treatment besides, solarization in combination with FYM and irrigation. It was found that solarization coupled with application of FYM and irrigation suppressed the development of corm rot to significant levels compared to soil solarization alone and non-solarized treatment. The differences between different treatments were generally significant. The study clearly establishes that six weeks of solarization

when supplemented with FYM and irrigation reduce the corm rot severity to appreciable levels as compared to check. The other combinations i.e. solarized irrigated and solarized amended with FYM also resulted significant suppression of the disease. Soil solarization has been found effective in checking the soil borne diseases in different crops economically (Raj, *et al.,* 1997, Raj & Kapoor, 1993 and Chattopadhyay and Sastry, 2001). The experimental findings confirm the utility of soil solarization in corm rot. Many biological processes including antagonist pathogen interaction which contribute to pathogen control are stimulated besides chemical and physical processes take place during soil solarization (Katan, *et al.*1983). However, according to Patel (2001) the most pronounced effect of soil solarization in disease control is physical one i.e. an increase in soil temperature for several hours daily during the solarization period. Earlier also soil solarization with transparent polythene mulch has been found to kill the propagules of *Fusarium* infecting watermelon (Mortyn and Hirtz, 1986) and tomato (Raj & Kapoor, 1993). Present studies have shown that amending the soil with FYM and application of irrigation in combination with soil solarization can be helpful in reducing the corm rot of saffron. Raj *et al.* (1995) suggested that in order to get better results soil should be kept moist during mulching to increase thermal sensitivity of resting structures and improve heat condition.

CHAPTER-VI

SUMMARY AND CONCLUSION

Corm rot of saffron has been observed to be one of the serious problems of saffron in Kashmir valley. It has mainly contributed for the decline in productivity per unit area year after year. Corm rot is a soil borne problem and leads to rotting of corms above root region which not only stops flower bearing

but also decreases the potential of corm multiplication during vegetative phase of the crop.

Present studies clearly established the seriousness of the problem in all saffron growing areas both in terms of the incidence and intensity. It has been of higher order in traditional Pampore area and comparatively of low order in other newer areas. The symptoms produced by the disease have been described and causal organisms identified. Rhizosphere studies that involve association of fungi and nematodes provided useful information as far as the etiology is concerned. Pathogenicity of fungi belonging to genera *Fusarium* namely *Fusarium solani, Fusarium oxysporum* and *Fusarium moniliforme* has been worked out and amongst them *Fusarium solani* was most predominant and virulent.

Management of the disease has been attempted by adopting three non-chemical, non-hazardous approaches. All the three have given positive indications.

Soil amendments FYM, poultry manure, mushroom compost and spent mushroom compost in the ratio of 4:1 and 5:1 were beneficial but FYM and poultry manure in the ratio of 4:1 were most useful.

Bioagents like *Trichoderma viride, Trichoderma harzianum, Gliocladium roseum* and *Aspergillus niger* were also studied in order to have antagonistic effect on *Fusarium solani.* All the bioagents exhibited the antagonistic effect but *Trichoderma viride* was the most successful bioagent.

Soil solarization, a novel concept for managing soil borne pathogens was investigated. Soil solarization in combination with FYM and irrigation had positive effect in checking corm rot.

It can be concluded as under:

- Corm rot incidence ranged from 4.00 – 40.00 per cent in 1999 and 4.66 – 42.00 per cent in 2000.
- The corm rot intensity ranged from 0.8 – 16.93 per cent in 1999 and 1.33 – 17.43 per cent during 2000.
- Incidence and intensity was highest in Pampore belt and lowest in other areas in Budgam and Anantnag.
- Symptoms produced by corm rot disease on foliage, corms and other plant parts together with affect in crop stages are described.
- Five fungi were isolated and identified from rotten corms of which three species of *Fusarium* namely *Fusarium solani, Fusarium*

oxysporum and *Fusarium moniliforme* were pathogenic. *Fusarium solani* was most dominant and virulent.

- Association of *Fusarium solani* and nematodes in the rhizosphere was established. Association of nematodes and *Fusarium solani* gave highest number of diseased corms compared to individual inoculation.

The occurrence of *Fusarium* species varied from stage to stage of crop development. *Fusarium solani* was mainly observed at digging and harvesting stages while other two species were in storage stage.

Among the organic amendments FYM (4:1 ratio) was found to be the most useful followed by poultry manure. The amendments also helped in increasing the yield.

Trichoderma viride has the superior antagonistic effect on *Fusarium solani* compared to other bioagents. *Trichoderma viride* had both volatile and non-volatile activity of inhibition.

Soil solarization for a period of six weeks coupled with application of FYM and irrigation was most beneficial in increasing the soil competitive mycoflora, increasing the yield and decreasing the corm rot incidence.

Fig. 2	Status of Saffron corm rot in selected locations of Kashmir (Incidence)

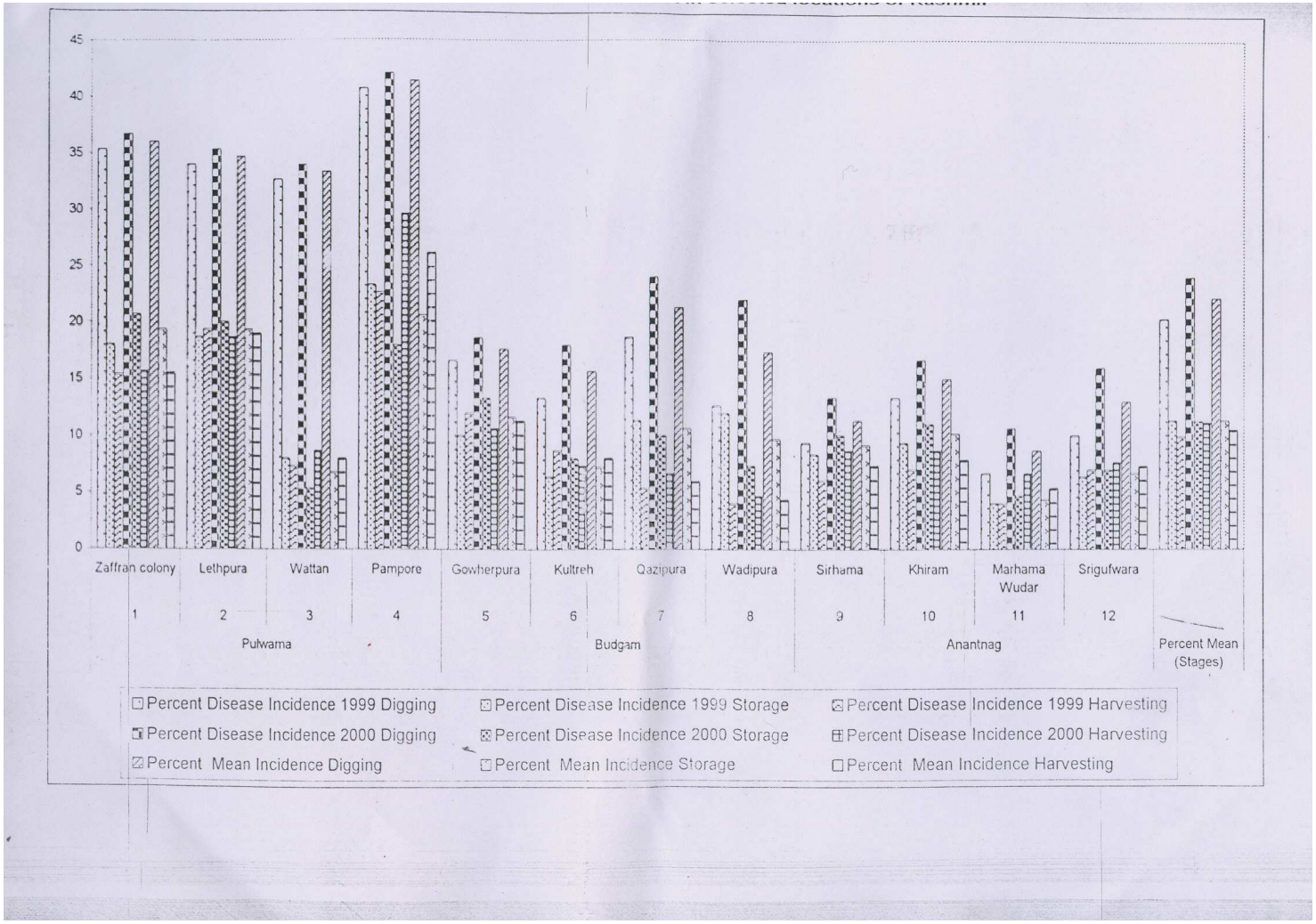

Fig. 3	Status of Saffron corm rot in selected locations of Kashmir (Intensity)

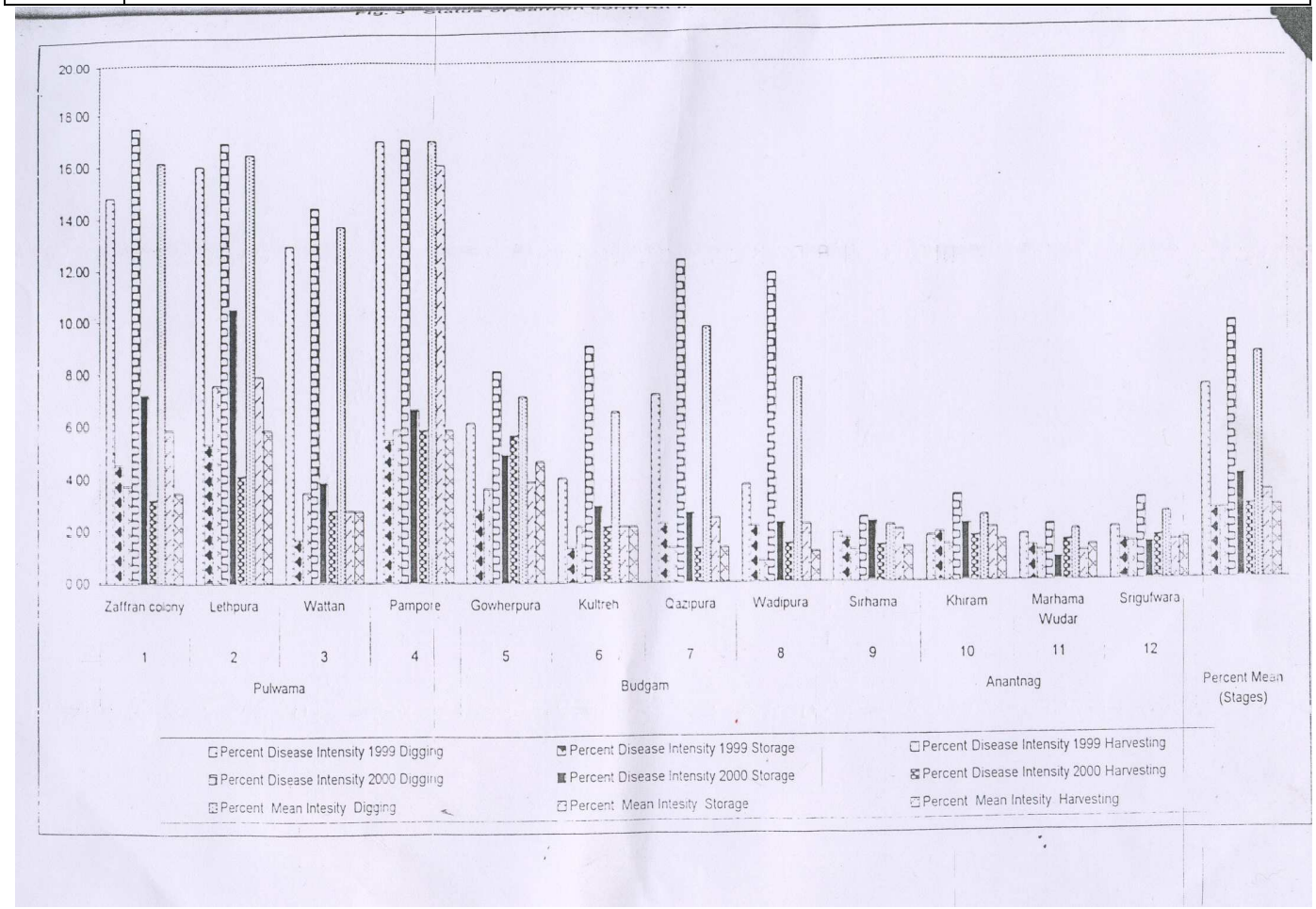

Fig. 4	Overall status of Saffron corm rot in three Districts of Kashmir valley

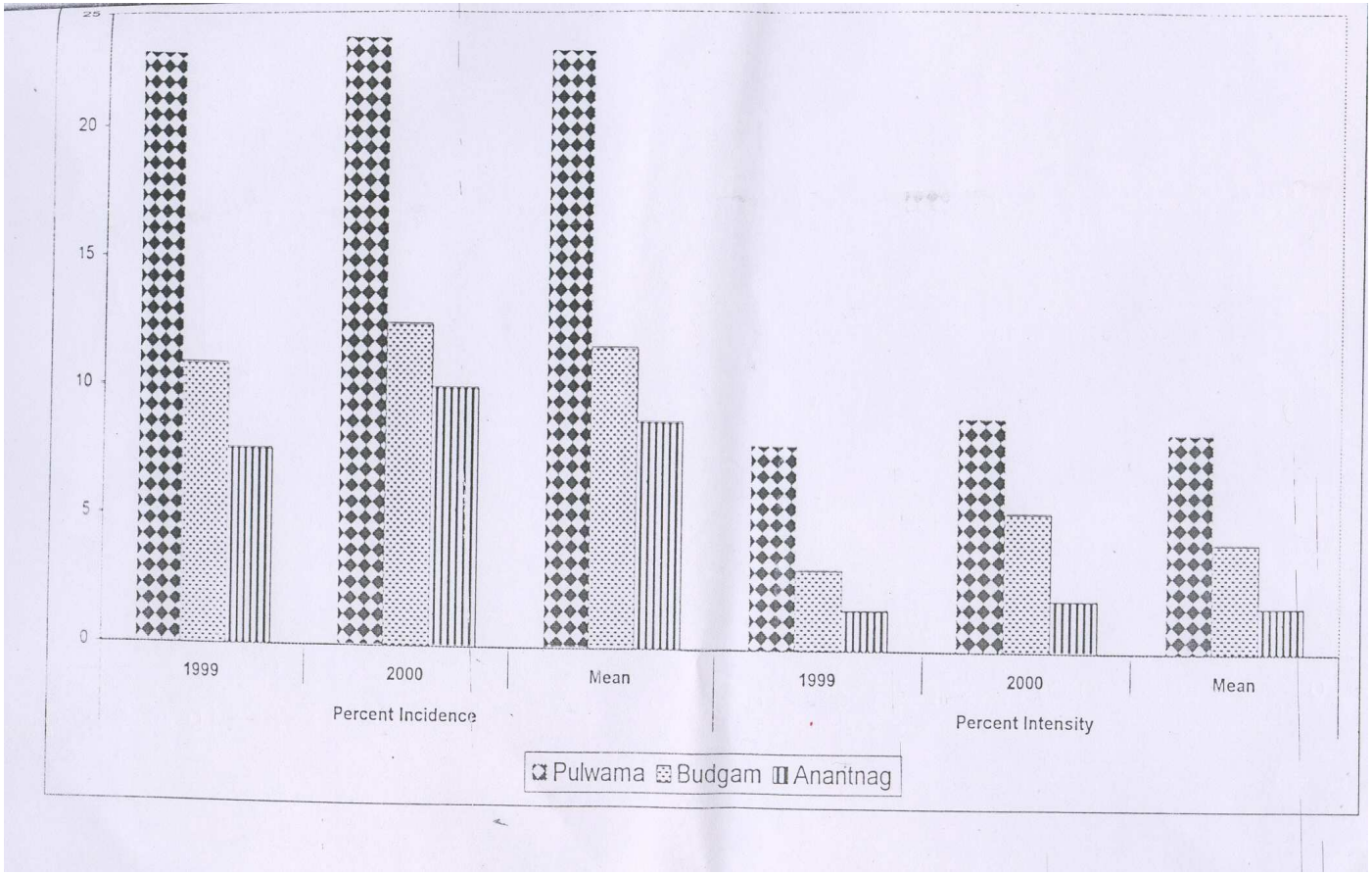

Fig. 5	Average growth of different *Fusarium* species on Richard's agar medium at 25±2^{0}C

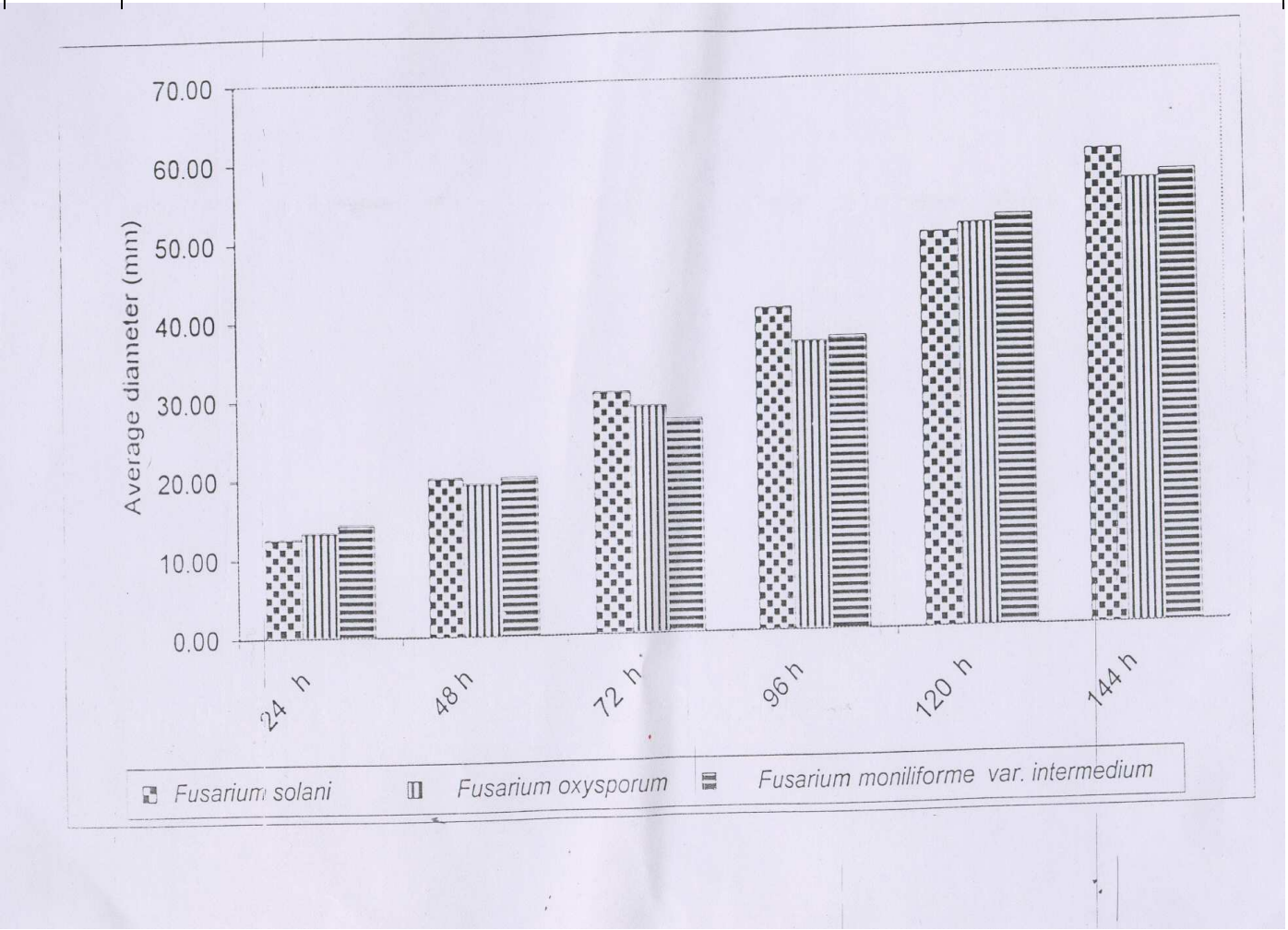

Plate 1:	Healthy Saffron Flower

Plate 2:	**(a) View of Saffron Field (Healthy)**
	(b) Saffron bed showing the corm rot diseases

Plate 3:	Saffron corm and symptoms of corm rot

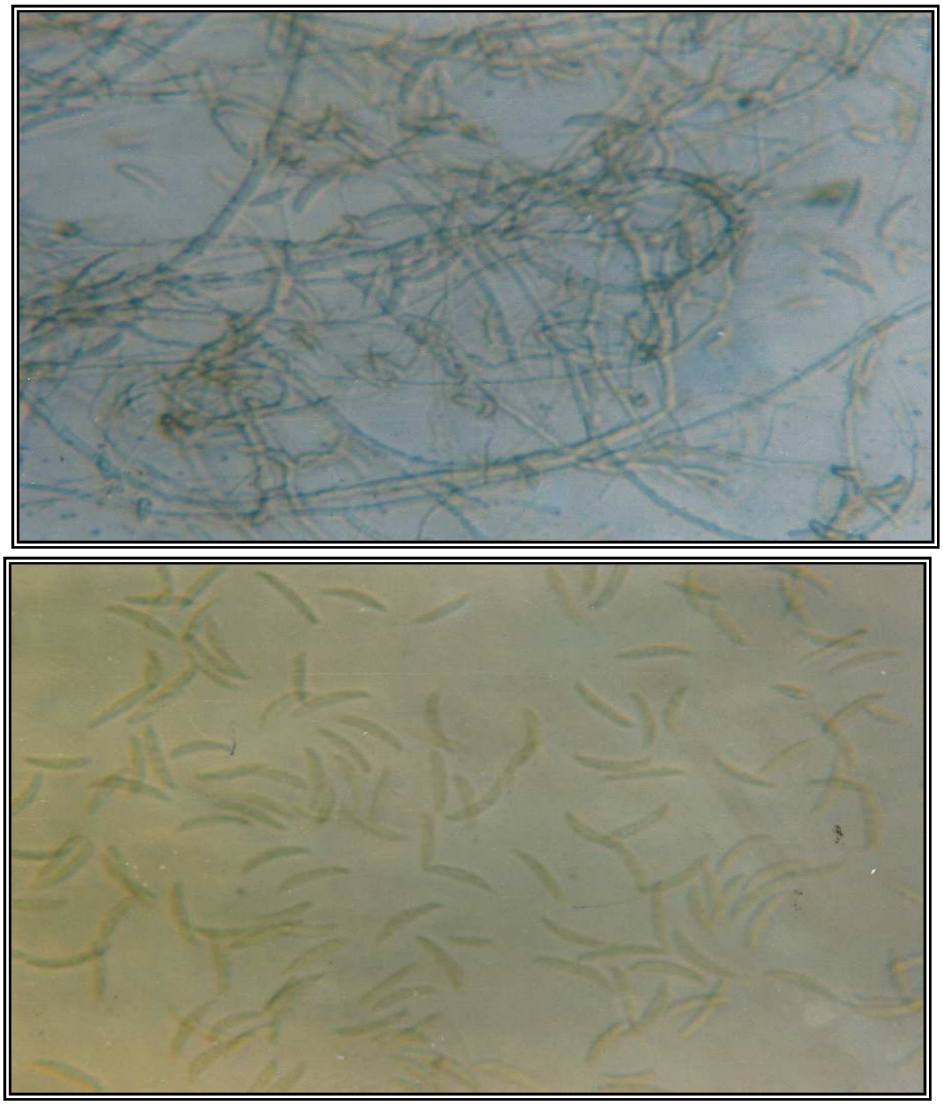

Plate 4(a):	***Fusarium solani***
	(a) Macro-conidia with mycelium
	(b) Macro-conidia

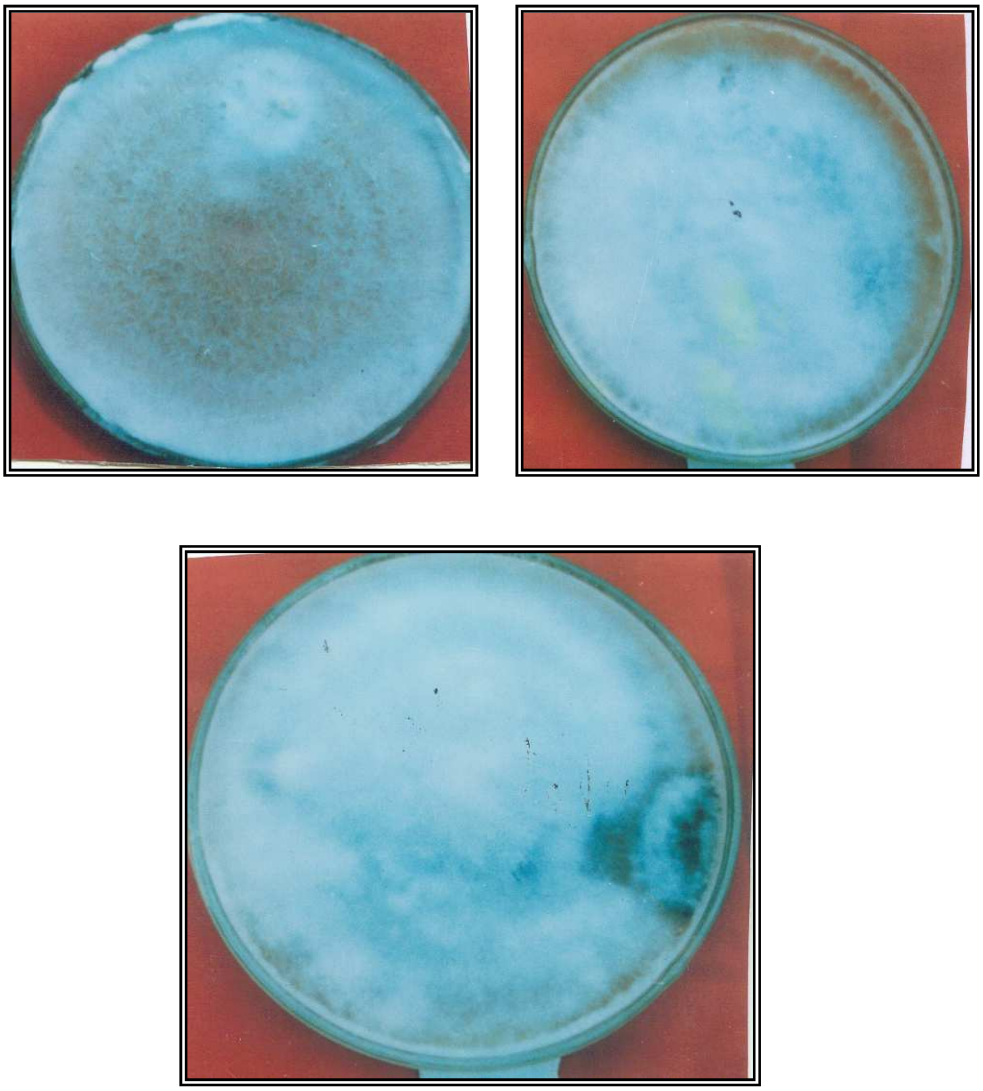

Plate 4(b):	***Fusarium* spp.**
	1. *Fusarium solani*
	2. *Fusarium moniliforme*
	3. *Fusarium oxysporum*

Plate 5:	**Pathogenicity response (*Fusarium solani*)**

Plate 6:	Corm rot symptoms at different stages of crop development

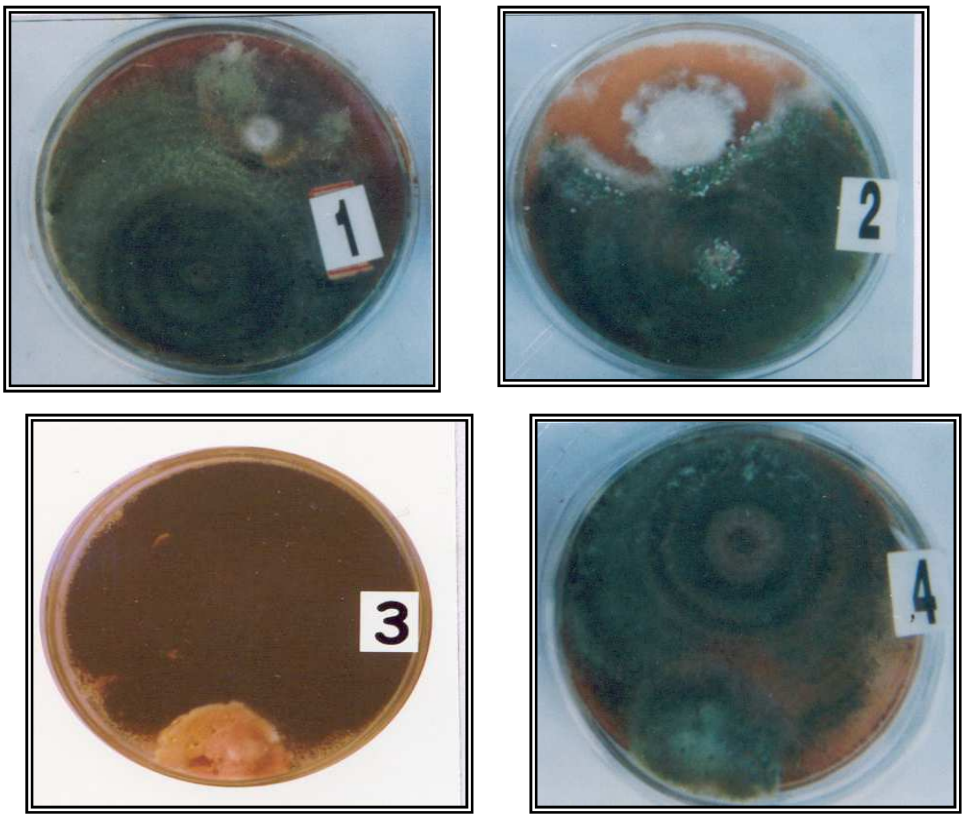

Plate 7:	**1. *Trichoderma viride***
	2. *Trichoderma harzianum*
	3. *Gliocladium virens*
	4. *Aspergillus niger*

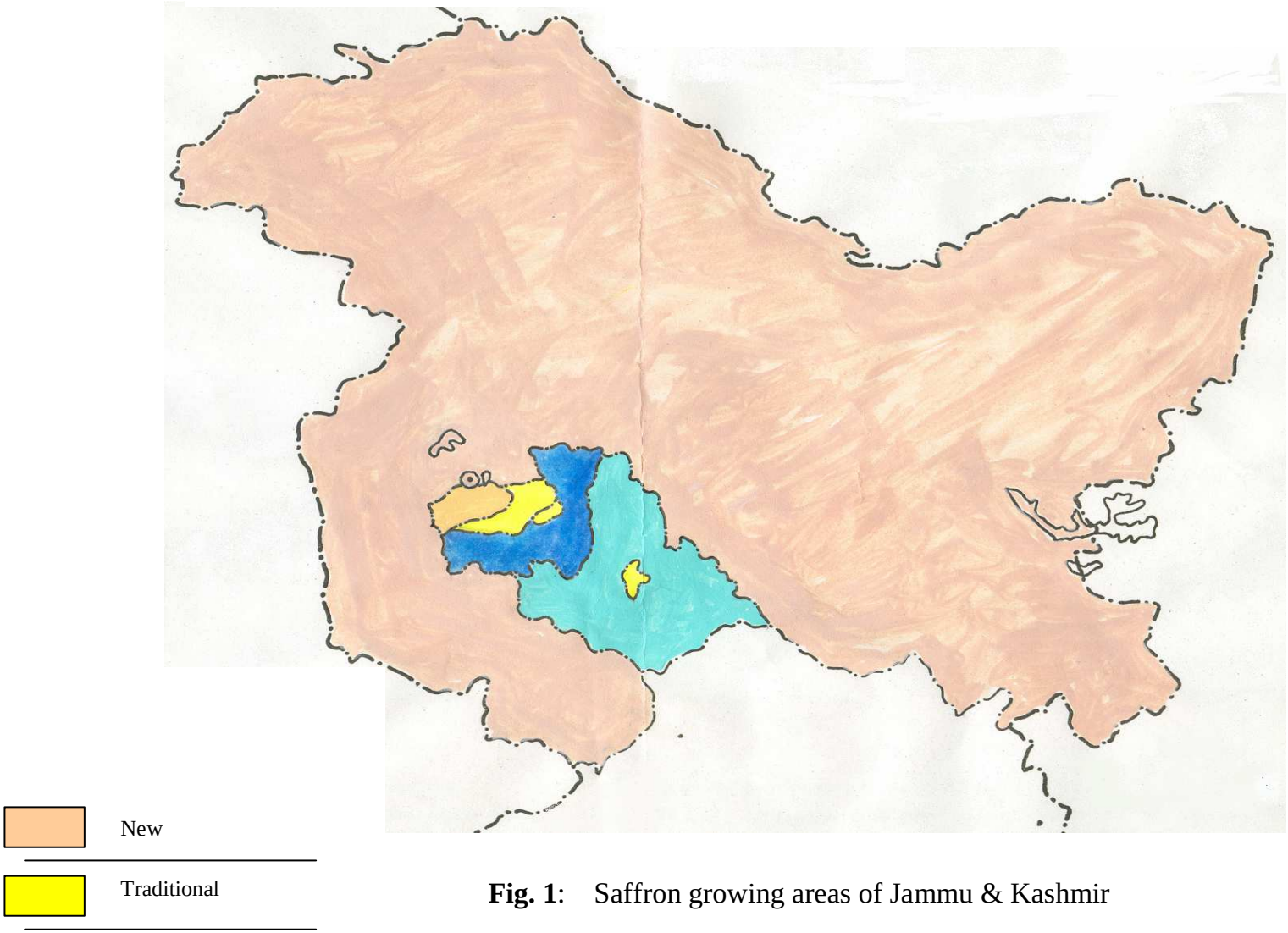

Fig. 1: Saffron growing areas of Jammu & Kashmir

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***Original not seen**