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# Status of Root and Foliar Fungal Diseases of Pulses at Different Agro-Climatic Zones of Uttar Pradesh, India

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**A B S T R A C T**

Pulses are high value crops and generally greater attention is paid to protect them against diseases caused by microbial pathogens after harvest during storage. An extensive field survey was conducted in 203 Blocks of 31 districts comprising three agro-climatic zones of Uttar Pradesh during 2011-12 and 2012-13 to find out the status of soil borne pathogens and bioagents in major pulse growing areas. In case of phytopathogens, *Fusarium* sp., *Rhizoctonia* sp., *Sclerotium rolfsii, Sclerotinia sclerotiorum, Phytophthora* sp., *Pythium* sp., *Colletotrichum* sp, *Aschochyta rabei, Alternaria* sp., *Pestalotiopsis* sp. were found as major disease causing agents in all 3 agro-climatic zones of Uttar Pradesh. Bioagents like *Trichoderma viride* and *Trichoderma harzianum* were prevalent in most part of the survey area of Uttar Pradesh. Other bioagents in terms of prevalence were *T. atroviride, T. ressei, T. asperellum, T. virens, T. longibrachiatum, T. koningii, T. citrinoviride, T. koningiopsis, T. aggressivum, T. aureoviride, T. erinaceum, T. pubscens, T. saturnisporum, T. tomentosum, T. minutisporum* and *T. spirale.* Based on the survey, it was found that majority of soil borne pathogens are responsible for low yield of the pulse crops. Interestingly, it was noted that the fields having much prevalence of bioagents showed low infestation of wilt/ root rot diseases.

## Introduction

Pulses play a major role in nutritional security for the people taking cereal based diet. Beside their dietary value and nitrogen fixing ability, pulses also play an important role in sustaining intensive agriculture by improving physical, chemical and biological properties of soil and are considered excellent crop for diversification of cereal based cropping system. India is the largest producer and consumer of pulses, it accounts for 33 percent of the world area and 22 percent of the world production of pulse. About 90 percent of the global pigeonpea, 65 percent of chickpea and 37 percent of lentil area falls in India, corresponding to 93 percent, 68 percent and 32 percent of the global production, respectively (FAOSTAT, 2014). Pulse crop are grown across the country with the highest share coming from Madhya Pradesh (24 percent), Uttar Pradesh (16 percent), Maharashtra (14 percent), Andhra Pradesh (10 percent), Karnataka (7 percent) and Rajasthan (6 percent), which together share about 77 percent of the total pulse production,

while the remaining 23 percent is contributed by Gujarat, Chhattisgarh, Bihar, Orissa and Jharkhand

Uttar Pradesh has large area under pulses (2522000 ha). However, the production (2197.2 th tonnes) of pulses (with an average of 871 kg/ ha yield) in this region does not commensurate with the acreage. The reason for this situation is invasion of pulses by several soil borne pathogens. No systematic information is available on the status of soil borne pathogens as well as bioagents present in this area.

Bioagent such as *Trichoderma sp.* is most commonly used biological control agent and have long been known as effective antagonistic against plant pathogenic fungi (Chet *et al.*, 1981; Papavizas, 1985; Chet, 1987; Kumar and Mukharjii, 1996). *Trichoderma* as a potent fungal biocontrol agent against a range of plant pathogens has attracted considerable scientific attention during last few decades (Tewari and Mukhopadhyay, 2001; Rini and Sulochana, 2007). The antifungal action of *Trichoderma* spp. is well documented against number of foliar and soil borne fungi like. *Fusarium* sp., *Pythium* sp., *Rhizoctonia solani*, *Sclerotium rolfsii*, in vegetables, field, fruit and industrial crops (Tran, 1998; Ngo *et al.*, 2006).

Therefore the present investigations were made to find out the actual situation of soil borne pathogens as well as bioagents present in Uttar Pradesh.

## Materials and Methods

### Survey

An extensive survey was conducted in 203 Blocks of 31 districts comprising three agro-climatic zones of Uttar Pradesh during 2011-12 & 2012-13 to observe the disease incidence in major pulse growing areas. In each district, randomly 15 soil samples from 5-6 cm depth were collected from the fields of villages adjoining to Block Headquarters. Each soil sample kept in parchment paper bags covered with polythene bags properly labeled with the name of district, block, village, name of the farmer, crop and date of the collection were brought to Bio-control Lab of the department of Plant Pathology, C.S. Azad University of Agriculture and Technology, Kanpur.

### Isolation, purification and identification of soil borne fungal pathogens

Isolation was made from 1g soil dissolved in 10 ml sterilized distilled water. Five fold serial dilutions were made from each soil sample and 0.5 ml of diluted sample was then poured on already prepared PDA medium in Petri plates. All Petri plates were incubated at 25+1ºC for 96 hours. Morphologically different colonies appeared on the plate were purified and observed under steriobincular microscope.

The colonies appeared as fungi like *Fusarium*, *Rhizoctonia*, *Sclerotium*, *Sclerotinia*, *Phytophthora*, *Pythium*, *Colletotrichum*, *Ascochyta*, *Alternaria*, *Pestalotiopsis* were separated. Hyphal tips of different fungi were picked up and transferred to another PDA plates. Purified fungi were identified based on their microscopic and morphological characters (Gilman, 1957; Barnett *et al.*, 1972; Nelson *et al.*, 1983). For confirmation at species level, the samples were sent to ITCC, New Delhi.

### Isolation, purification and identification of fungal bioagents

From the rhizospheric soil samples, *Trichoderma* species were isolated by dilution plate technique (Johnson, 1957). *Trichoderma*

selective medium (TSM) was used for isolation (Elad *et al.,* 1991). After few days of incubation, colonies appear in varying densities, depending upon the amount of dilution from the original material. The fungal colonies developed in the plates were sub cultured and purified on TSM slants. For confirmation at species level, the samples were sent to ITCC, New Delhi.

## Prevalence of pathogens and bioagents

Number of colonies for each pathogen/ bioagent developed from the soil samples was counted and percent recovery of each pathogen and bioagent was worked out. From each soil sample, 10 isolations were made. Based on the frequency of the pathogen/ bioagent appeared on PDA plates, number of pathogen and bioagents was counted and prevalence percentage was determined. The observations recorded are summarized in Tables 1 and 2.

## Statistical analysis

All experiments were set up in a complete randomized design. One-way ANOVA was used to analyze differences between applied treatments. A general linear model option of the analysis system SAS (SAS Institute Inc., 1996) was used to perform the ANOVA. Region-wise prevalence correlation coefficient of bioagents vs. pathogens was also worked out (Table 3).

## Results and Discussion

### Prevalence of phytopathogens isolated from soil samples of different places of Uttar Pradesh

It is evident from Table 1 that, out of 34 Blocks of six districts surveyed in Bundelkhand Region, five pathogens viz., *Fusarium*, *Rhizoctonia*, *Sclerotium rolfsii*, *Sclerotinia sclerotiorum*, *Phytophthora* and *Ascochyta rabei* were isolated. Four types of pathogens were isolated from eight Blocks of Banda, seven Blocks of Hamirpur and four Blocks of Lalitpur districts; three types of pathogens were isolated from five Blocks of Jalaun and six blocks of Jhansi and only two types of pathogens could be isolated from four Blocks of Mahoba. In general, 26.85 per cent pathogens were isolated from the entire zone.

Statistically, *Fusarium* sp. given high response in Banda, Hamirpur, Jhansi, Mahoba and Lalitpur followed by *Rhizoctonia* sp. *Sclerotinia sclerotiorum* and *Phytophthora* sp. were statistically at par to each other and given same response in Bundelkhand region.

Out of 76 Blocks of eleven districts surveyed in Central Region, eleven pathogens viz., *Fusarium*, *Rhizoctonia*, *Sclerotium rolfsii*, *Sclerotinia sclerotiorum*, *Phytophthora*, *Pythium*, *Colletotrichum*, *Ascochyta rabei*, *Alternaria*, and *Pestalotiopsis* were isolated.

Maximum nine type of pathogens were isolated from six Blocks of Fatehpur; eight type of pathogens were isolated from eight Blocks of Etawah, seven Blocks of Kanpur Nagar, eight Blocks of Raebareli and seven Blocks of Unnao; seven type of pathogens were isolated from five Blocks of Hardoi, five Blocks of Kaushambi and seven Blocks of Lucknow and six types of pathogens were isolated from seven Blocks of Auraiya, six Blocks of Kanpur Dehat and ten Blocks of Sitapur. In general, 26.19 per cent pathogens were isolated from the entire zone.

Statistically, *Fusarium* sp. given high response in Fatehpur, Raibareilly, Kanpur Nagar and Kanpur Dehat. *Rhizoctonia* sp. and *Alternaria* sp. given same response in Raibareilly, Kaushambi and Fatehpur. *Phytophthora* sp., *Pythium* sp., *S.*

*sclerotiorum*, *Sclerotium rolfsii* and *Ascochyta* sp. were statistically at par with each other in Fatehpur, Kaushambi, Raebareli and Unnao.

Out of 93 Blocks of fourteen districts surveyed in Eastern Region, ten pathogens viz., *Fusarium*, *Rhizoctonia*, *Sclerotium rolfsii*, *Sclerotinia sclerotiorum*, *Phytophthora*, *Pythium*, *Colletotrichum*, *Ascochyta rabei*, *Alternaria* and sterility mosaic virus were isolated.

Maximum eight type of pathogens were isolated from six Blocks of Faizabad; seven type of pathogens were isolated from nine Blocks each of Allahabad, Azamgarh, Jaunpur and Sultanpur, eight Blocks of Barabanki, six Blocks of Sonbhadra and five Blocks each of Gonda and Sant Ravidas Nagar; six type of pathogens were isolated from five Blocks of Bahraich; five type of pathogens were isolated from six Blocks each of Mirzapur and Varanasi and five Blocks of Ghazipur and only four type of pathogens were isolated from five Blocks of Pratapgarh.

In general, 25.24 per cent pathogens were isolated from the entire zone (Figs. 1, 2 & 3).

Statistically, *Fusarium* sp. given high response in Barabanki, Gonda, Sonbhadra followed by *Rhizoctonia* sp., *S. sclerotiorum*, *Sclerotium rolfsii*, *Phytophthora* sp., *Alternaria* sp. and *Pythium* sp. have also given some incidence in Sonbhadra, Barabanki, Azamgarh, Gonda, Faizabad and Varanasi.

The isolated fungi were previously recorded as the main causal of root diseases of surveyed pulse and vegetable crops by Jones (2001), Jude and Richard (2001), Elizabeth *et al.,* (2001), Pernezny *et al.,* (2003), Momol and Pernezny (2005), Trivedi and Gurha (2006), Gurha *et al.,* (2007).

**Prevalence of bioagents isolated from soil samples of different places of Uttar Pradesh**

It is evident from Table 2 that a total of nine *Trichoderma* species viz; *T. harzianum, T. viride, T. virens, T. asperellum, T. koningii, T. ressei, T. aureoviride, T. longibrachiatum* and *T. atroviride* could be isolated from soil samples of Bundelkhand region of U. P. 7 species of bioagents from 7 Blocks of Hamirpur and 5 Blocks of Jalaun; 6 species of bioagents from 8 Blocks of Banda; 5 species of bioagents from 5 Blocks of Jhansi; 4 species of bioagents from 4 Blocks of Mahoba and 3 species of bioagents from 4 Blocks of Lalitpur could be isolated. In general, 20.61 per cent bioagents were isolated from this zone.

*T. viride* has given most effective response to the pathogens while, *T. harzianum, T. asperellum* and *T. koningii* were recorded statistically at par given same response over pathogens in Hamirpur, Jhansi, Lalitpur and Mahoba districts of Bundelkhand region.

In addition, fifteen *Trichoderma* species viz; *T. harzianum, T. viride, T. virens, T. asperellum, T.* atroviride, T. *koningii, T. ressei, T. citrinoviride, T. spirale, T. erinaceum, T. pubscens, T. tomentosum, T. minutisporum, T. koningiopsis* and *T. longibrachiatum* could be isolated from soil samples of Central region of U.P. 10 species of bioagents from 7 Blocks of Kanpur Nagar, 8 species of bioagents from 8 Blocks of Etawah and 6 Blocks of Kanpur Dehat; 7 species of bioagents from 10 Blocks of Sitapur; 6 species of bioagents from 8 Blocks of Raebareli, 7 Blocks of Auraiya, 6 Blocks of Fatehpur, 5 Blocks each of Hardoi and Kaushambi and 5 species of bioagents from 7 Blocks each of Lucknow and Unnao. In general, 20.89 per cent bioagents were isolated from this zone.

**Table.1** Prevalence of phytopathogens isolated from soil samples of different places of Uttar Pradesh

| District | Pathogens (%) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bundelkhand Region** | ***Fusarium* sp.** | ***Rhizoctonia* sp.** | ***Sclerotium rolfsii*** | ***S. sclerotiorum*** | ***Phytophthora* sp.** | ***Pythium* sp.** | ***Colletotrichum* sp** | ***Aschochyta rabei*** | ***Alternaria* sp.** | ***Pestalotiopsis* sp.** | | **Mean** | **SD** |
| Banda | 17.5 | 3.75 | 3.75 | 0.0 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 2.5 | 5.2 |
| Hamirpur | 12.8 | 10.0 | 3.3 | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 2.5 | 4.6 |
| Jalaun | 12.0 | 6.0 | 0.0 | 0.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 2.0 | 3.9 |
| Jhansi | 16.6 | 5.0 | 5.0 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | | 2.6 | 5.1 |
| Lalitpur | 12.5 | 7.5 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | | 2.5 | 4.2 |
| Mahoba | 17.5 | 12.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 2.7 | 6.2 |
| **SE (M) ±** | **1.04** | | | | | | | | | | | | |
| **CD (5%)** | **3.06** | | | | | | | | | | | | |
| **Central Region** | | | | | | | | | | | | | |
| Auraiya | 12.8 | 2.8 | 0.0 | 1.4 | 0.0 | 1.4 | 1.4 | 0.0 | 4.2 | 0.0 | | 2.2 | 3.8 |
| Etawah | 11.2 | 2.5 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0.0 | 2.5 | 0.0 | | 2.0 | 3.2 |
| Fatehpur | 13.3 | 3.3 | 1.6 | 1.6 | 1.6 | 3.3 | 1.6 | 1.6 | 3.3 | 0.0 | | 2.8 | 3.7 |
| Hardoi | 8.0 | 4.0 | 2.0 | 2.0 | 2.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 2.2 | 2.4 |
| Kanpur Dehat | 10.0 | 5.0 | 1.6 | 1.6 | 0.0 | 0.0 | 0.0 | 3.3 | 3.3 | 0.0 | | 2.3 | 3.1 |
| Kanpur Nagar | 12.8 | 2.8 | 1.4 | 1.4 | 1.4 | 0.0 | 1.4 | 1.4 | 0.0 | 4.2 | | 2.4 | 3.7 |
| Kaushambi | 12.0 | 4.0 | 4.0 | 2.0 | 0.0 | 2.0 | 2.0 | 0.0 | 4.0 | 0.0 | | 2.7 | 3.5 |
| Lucknow | 8.5 | 2.8 | 1.4 | 0.0 | 2.8 | 1.4 | 0.0 | 0.0 | 1.4 | 1.4 | | 1.8 | 2.5 |
| Raebareli | 11.2 | 6.2 | 2.5 | 1.2 | 6.2 | 1.2 | 1.2 | 0.0 | 2.5 | 0.0 | | 2.9 | 3.5 |
| Sitapur | 11.0 | 4.0 | 3.0 | 0.0 | 0.0 | 2.0 | 0.0 | 3.0 | 4.0 | 0.0 | | 2.5 | 3.3 |
| Unnao | 10.0 | 2.8 | 0.0 | 1.4 | 1.4 | 1.4 | 1.4 | 2.8 | 4.2 | 0.0 | | 2.3 | 2.9 |
| **SE (M) ±** | **0.41** | | | | | | | | | | | | |
| **CD (5%)** | **1.15** | | | | | | | | | | | | |
| **Eastern Region** | | | | | | | | | | | | | |
| Allahabad | 12.2 | 3.3 | 1.1 | 1.1 | 2.2 | 1.1 | 0.0 | 0.0 | 1.1 | 0.0 | | 2.0 | 3.5 |
| Azamgarh | 11.1 | 5.5 | 0.0 | 2.2 | 1.1 | 1.1 | 1.1 | 0.0 | 5.5 | 0.0 | | 2.5 | 3.5 |
| Bahraich | 10.0 | 2.0 | 2.0 | 4.0 | 0.0 | 2.0 | 4.0 | 0.0 | 0.0 | 0.0 | | 2.2 | 3.0 |
| Barabanki | 17.5 | 3.75 | 2.5 | 2.5 | 2.5 | 1.2 | 0.0 | 0.0 | 1.2 | 0.0 | | 2.8 | 5.0 |
| Faizabad | 11.6 | 1.6 | 1.6 | 3.3 | 1.6 | 0.0 | 1.6 | 0.0 | 1.6 | 0.0 | | 2.4 | 3.3 |
| Ghazipur | 10.0 | 8.0 | 2.0 | 2.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 2.2 | 3.5 |
| Gonda | 10.0 | 4.0 | 4.0 | 0.0 | 2.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 | | 2.5 | 3.0 |
| Jaunpur | 15.5 | 2.2 | 1.1 | 1.1 | 2.2 | 2.2 | 0.0 | 0.0 | 2.2 | 0.0 | | 2.4 | 4.5 |
| Mirzapur | 11.6 | 5.0 | 1.6 | 0.0 | 3.3 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | | 2.1 | 3.6 |
| Pratapgarh | 10.0 | 8.0 | 0.0 | 4.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | | 2.2 | 3.6 |
| Sant Ravidas Nagar | 8.0 | 4.0 | 2.0 | 0.0 | 2.0 | 2.0 | 2.0 | 0.0 | 2.0 | 0.0 | | 2.0 | 2.4 |
| Sonbhadra | 13.3 | 5.0 | 3.3 | 3.3 | 0.0 | 1.6 | 1.6 | 0.0 | 1.6 | 0.0 | | 2.7 | 3.9 |
| Sultanpur | 6.6 | 4.4 | 2.2 | 3.3 | 2.2 | 0.0 | 0.0 | 0.0 | 2.2 | 0.0 | | 2.0 | 2.1 |
| Varanasi | 10.0 | 8.3 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 1.6 | 1.6 | 0.0 | | 2.1 | 3.6 |
| **SE (M) ±** | **0.46** | | | | | | | | | | | | |
| **CD (5%)** | **1.28** | | | | | | | | | | | | |

**Table.2** Prevalence of bioagents isolated from soil samples of different places of Uttar Pradesh

| District | Bio-agents (%) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bundelkhand Region** | ***T. harzian-um*** | ***T. viride*** | ***T. virens*** | ***T. aspere-llum*** | ***T. atro-viride*** | ***T. longibra-chiatum*** | ***T. koningii*** | ***T. reesei*** | ***T. aggres-sium*** | ***T. citrino-viride*** | ***T. spirale*** | ***T. erinac-eum*** | ***T. pubscens*** | ***T. tomen-tosum*** | ***T. minutis-porum*** | ***T. koningio-psis*** | ***T. saturn-isporum*** | ***T. aureov-iride*** | ***P. fluoresc-ens*** | **Mean** | **SD** |
| Banda | 3.75 | 8.75 | 2.5 | 1.2 | 0.0 | 1.2 | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.5 |
| Hamirpur | 5.7 | 10 | 1.4 | 5.7 | 0.0 | 0.0 | 1.4 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.5 |
| Jalaun | 6.0 | 4.0 | 0.0 | 2.0 | 2.0 | 2.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.9 |
| Jhansi | 1.6 | 10 | 0.0 | 3.3 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 | 0.6 | 1.5 |
| Lalitpur | 0.0 | 15 | 0.0 | 2.5 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.9 |
| Mahoba | 5.0 | 10 | 0.0 | 2.5 | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.9 |
| **SE (M) ±** | **1.07** | | | | | | | | | | | | | | | | | | | | |
| **CD (5%)** | **3.22** | | | | | | | | | | | | | | | | | | | | |
| **Central region** | | | | | | | | | | | | | | | | | | | | | |
| Auraiya | 7.1 | 5.7 | 1.4 | 0.0 | 5.7 | 0.0 | 1.4 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 1.6 |
| Etawah | 3.75 | 2.5 | 1.25 | 1.25 | 1.25 | 0.0 | 3.75 | 3.75 | 0.0 | 0.0 | 3.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 1.5 |
| Fatehpur | 1.6 | 6.6 | 3.3 | 1.6 | 0.0 | 0.0 | 0.0 | 3.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.9 |
| Hardoi | 6.0 | 8.0 | 2.0 | 2.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.8 |
| Kanpur Dehat | 0.0 | 5.0 | 0.0 | 1.6 | 3.3 | 1.6 | 3.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 1.4 |
| Kanpur Nagar | 4.2 | 8.5 | 5.7 | 2.8 | 0.0 | 1.4 | 0.0 | 2.8 | 0.0 | 5.7 | 5.7 | 4.2 | 4.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 2.2 |
| Kaushambi | 0.0 | 4.0 | 2.0 | 2.0 | 4.0 | 0.0 | 2.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 1.2 |
| Lucknow | 2.8 | 1.4 | 0.0 | 0.0 | 1.4 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.5 |
| Raebareli | 2.5 | 7.5 | 0.0 | 0.0 | 1.2 | 0.0 | 1.2 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.25 | 0.0 | 0.0 | 0.0 | 0.6 | 1.6 |
| Sitapur | 4.0 | 4.0 | 3.0 | 2.0 | 2.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.9 |
| Unnao | 0.0 | 5.7 | 1.4 | 0.0 | 2.8 | 1.4 | 1.4 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.0 |
| **SE (M) ±** | **0.52** | | | | | | | | | | | | | | | | | | | | |
| **CD (5%)** | **1.47** | | | | | | | | | | | | | | | | | | | | |
| **Eastern Region** | | | | | | | | | | | | | | | | | | | | | |
| Allahabad | 0.0 | 6.6 | 2.2 | 2.2 | 2.2 | 1.1 | 1.1 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.3 | 0.0 | 1.1 | 0.8 | 1.1 |
| Azamgarh | 2.2 | 3.3 | 3.3 | 1.1 | 3.3 | 1.1 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.0 |
| Bahraich | 6.0 | 6.0 | 0.0 | 2.0 | 4.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.2 |
| Barabanki | 3.7 | 7.5 | 1.2 | 2.5 | 1.2 | 2.5 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.9 |
| Faizabad | 5.0 | 1.6 | 0.0 | 3.3 | 3.3 | 1.6 | 0.0 | 3.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 1.3 |
| Ghazipur | 12 | 2.0 | 4.0 | 2.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.7 |
| Gonda | 0.0 | 4.0 | 4.0 | 2.0 | 2.0 | 0.0 | 2.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 1.2 |
| Jaunpur | 5.5 | 7.7 | 2.2 | 1.1 | 5.5 | 0.0 | 1.1 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 1.4 |
| Mirzapur | 5.0 | 8.3 | 3.3 | 0.0 | 3.3 | 3.3 | 3.3 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 1.7 |
| Pratapgarh | 2.0 | 6.0 | 2.0 | 2.0 | 2.0 | 0.0 | 0.0 | 6.0 | 6.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 2.1 |
| Sonbhadra | 5.0 | 3.3 | 1.6 | 3.3 | 3.3 | 1.6 | 1.6 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 1.2 |
| SR Nagar | 4.0 | 8.0 | 0.0 | 2.0 | 4.0 | 6.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 1.8 |
| Sultanpur | 8.8 | 5.5 | 1.1 | 0.0 | 2.2 | 2.2 | 0.0 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.8 |
| Varanasi | 10 | 5.0 | 1.6 | 0.0 | 1.6 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.5 |
| **SE (M) ±** | **0.54** | | | | | | | | | | | | | | | | | | | | |
| **CD (5%)** | **1.51** | | | | | | | | | | | | | | | | | | | | |

**Table.3** Region-wise prevalence correlation coefficient

| **Bundelkhand** | **Correlation Coefficient** | | | |
|---|---|---|---|---|
| **Bioagents** | **Pathogens** | | | |
| | ***Fusarium* sp.** | ***Rhizoctonia* sp.** | ***S. rolfsii*** | ***Phytophthora* sp.** |
| *T. harzianum* | -0.0647 | 0.3314 | -0.7848 | 0.6150 |
| *T. viride* | 0.0423 | 0.2359 | 0.6603 | -0.8277 |
| *T. asperellum* | -0.3468 | 0.4609 | 0.1924 | -0.2847 |
| *T. koningii* | 0.4762 | 0.6966 | -0.2442 | -0.5939 |

| **Central** | **Correlation Coefficient** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Bioagents** | **Pathogens** | | | | | | | | |
| | ***Fusarium* sp.** | ***Rhizoctonia* sp.** | ***S. rolfsii*** | ***S. sclerotiorum*** | ***Phytophthora* sp.** | ***Pythium* sp.** | ***Colletotrichum* sp.** | ***Aschochyta* sp.** | ***Alternaria* sp.** |
| *T. harzianum* | 0.0204 | -0.2594 | -0.2535 | -0.1354 | 0.0015 | 0.0204 | -0.2033 | -0.4438 | -0.3879 |
| *T. viride* | 0.2456 | 0.3076 | -0.0736 | 0.5595 | 0.2673 | -0.0685 | 0.2203 | 0.0686 | -0.3454 |
| *T. virens* | 0.5247 | -0.3817 | 0.0829 | 0.1319 | -0.3059 | 0.0834 | 0.3119 | 0.1751 | -0.2889 |
| *T. asperellum* | 0.2025 | -0.0152 | 0.4957 | 0.2760 | -0.4284 | -0.0389 | -0.0389 | 0.2252 | -0.3530 |
| *T. atroviride* | -0.0141 | 0.0182 | -0.1219 | 0.2117 | -0.4781 | -0.0869 | 0.0694 | -0.0545 | 0.5717 |
| *T. koningii* | 0.0616 | 0.1189 | 0.0804 | 0.0178 | -0.3559 | -0.2881 | 0.0185 | 0.2025 | 0.5209 |
| *T. ressei* | 0.4225 | -0.2907 | -0.4481 | 0.7133* | -0.2873 | -0.1284 | 0.5204 | 0.0530 | 0.0737 |

| **Eastern** | **Correlation Coefficient** | | | | | | |
|---|---|---|---|---|---|---|---|
| **Bioagents** | **Pathogens** | | | | | | |
| | ***Fusarium* sp.** | ***Rhizoctonia* sp.** | ***S. rolfsii*** | ***S. sclerotiorum*** | ***Phytophthora* sp.** | ***Pythium* sp.** | ***Alternaria* sp.** |
| *T. harzianum* | -0.2842 | 0.3532 | -0.1072 | 0.0344 | -0.1756 | -0.0939 | -0.2360 |
| *T. viride* | 0.5031 | -0.1201 | 0.0699 | 0.0086 | 0.2517 | 0.1509 | -0.2609 |
| *T. virens* | -0.0992 | 0.4201 | -0.0723 | -0.5750* | 0.2138 | 0.3219 | 0.1266 |
| *T. asperellum* | 0.1718 | -0.3685 | 0.2975 | 0.2172 | -0.2656 | 0.2142 | -0.1107 |
| *T. atroviride* | 0.2038 | -0.6118* | -0.0316 | 0.0551 | 0.0870 | 0.2831 | 0.2689 |
| *T. longibrachiatum* | 0.2075 | -0.2341 | 0.4368 | 0.2745 | -0.0114 | 0.0965 | -0.0523 |
| *T. ressei* | -0.1976 | 0.2949 | -0.0296 | -0.1212 | 0.0387 | -0.2240 | -0.4453 |

**Fig.1** Prevalence of bio-agents and phytopathogens in Bundelkhand region of U.P.

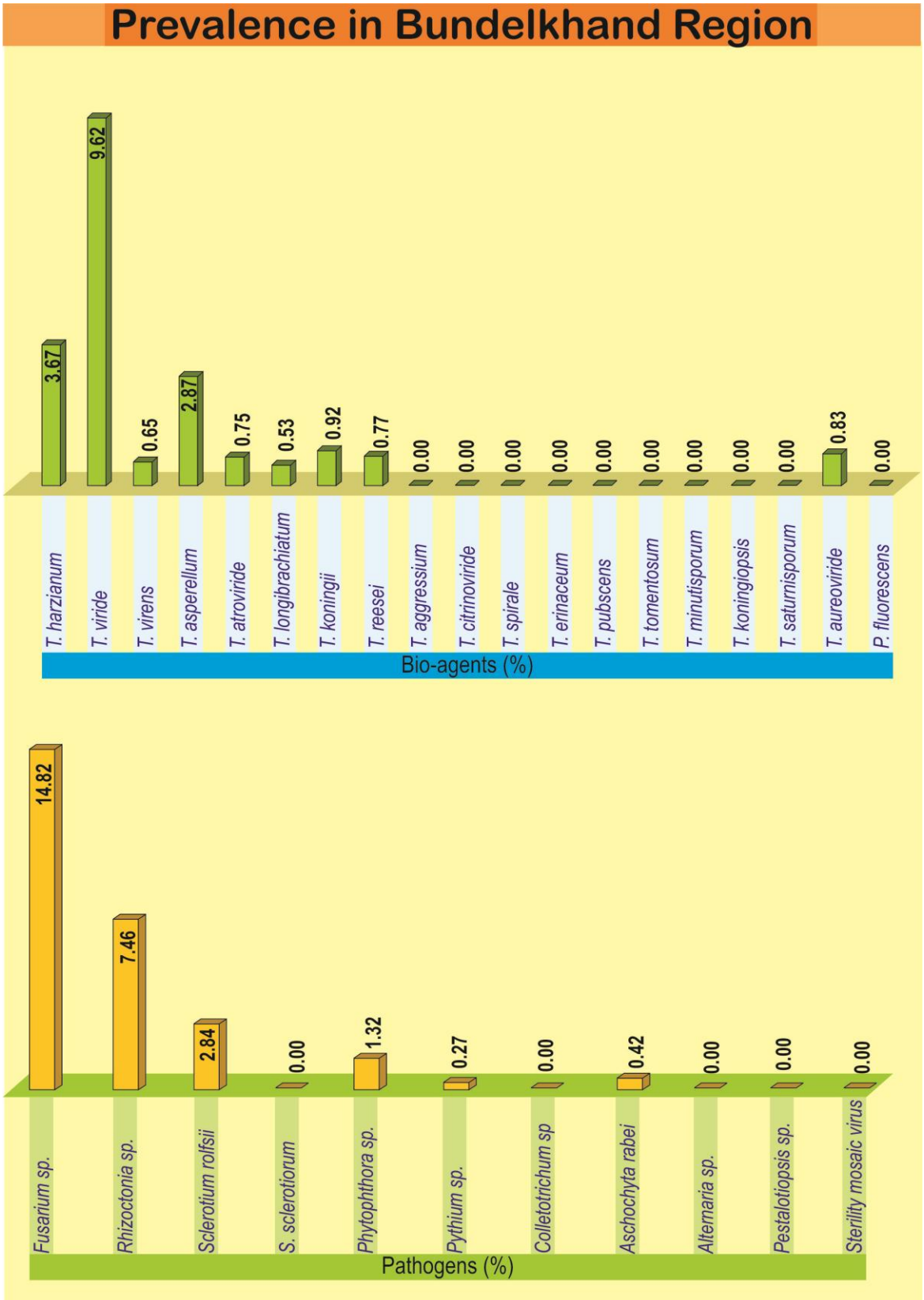


**Fig.2** Prevalence of bio-agents and phytopathogens in Central region of U.P.

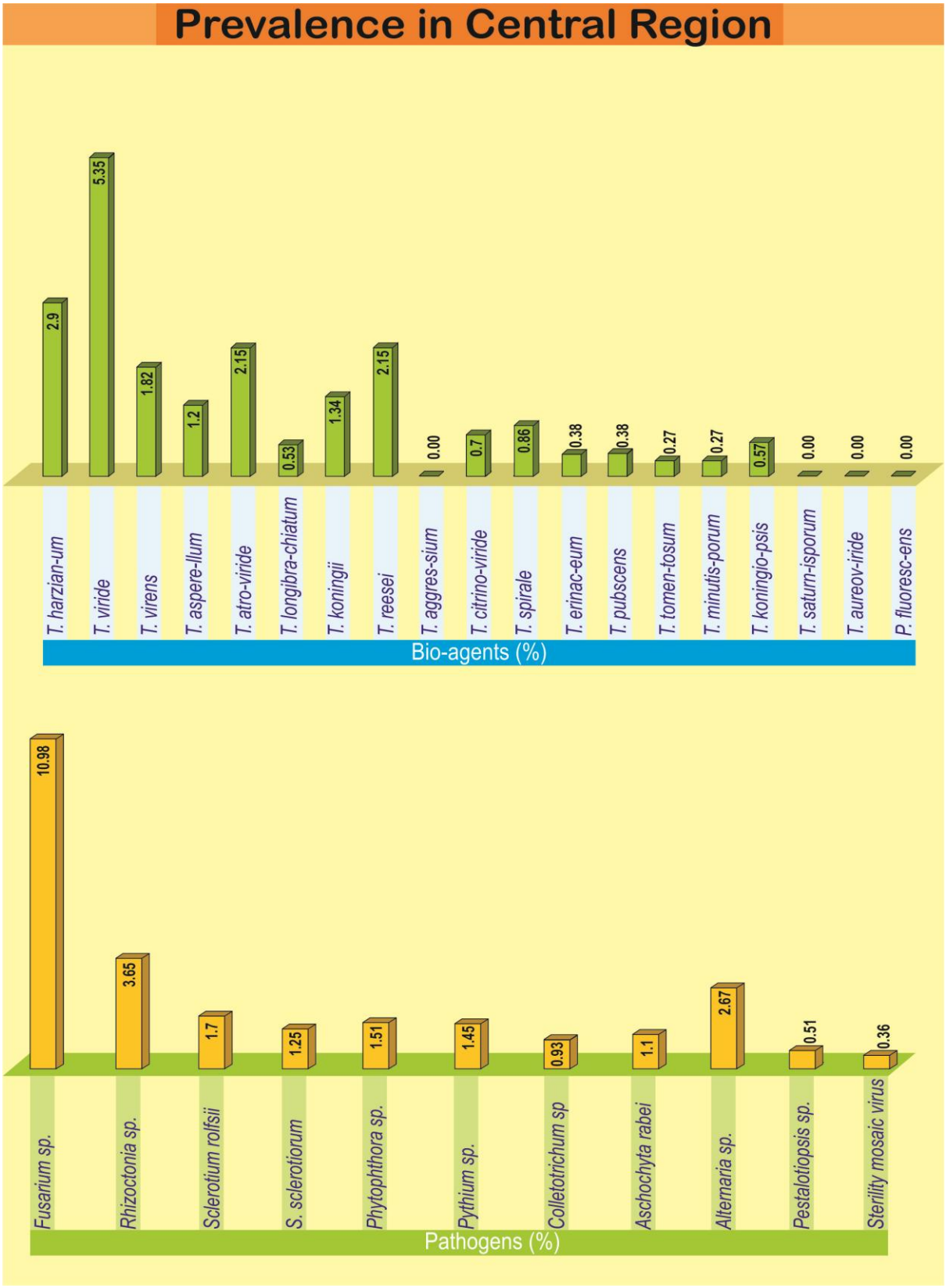


**Fig.3** Prevalence of bio-agents and phytopathogens in Eastern region of U.P.

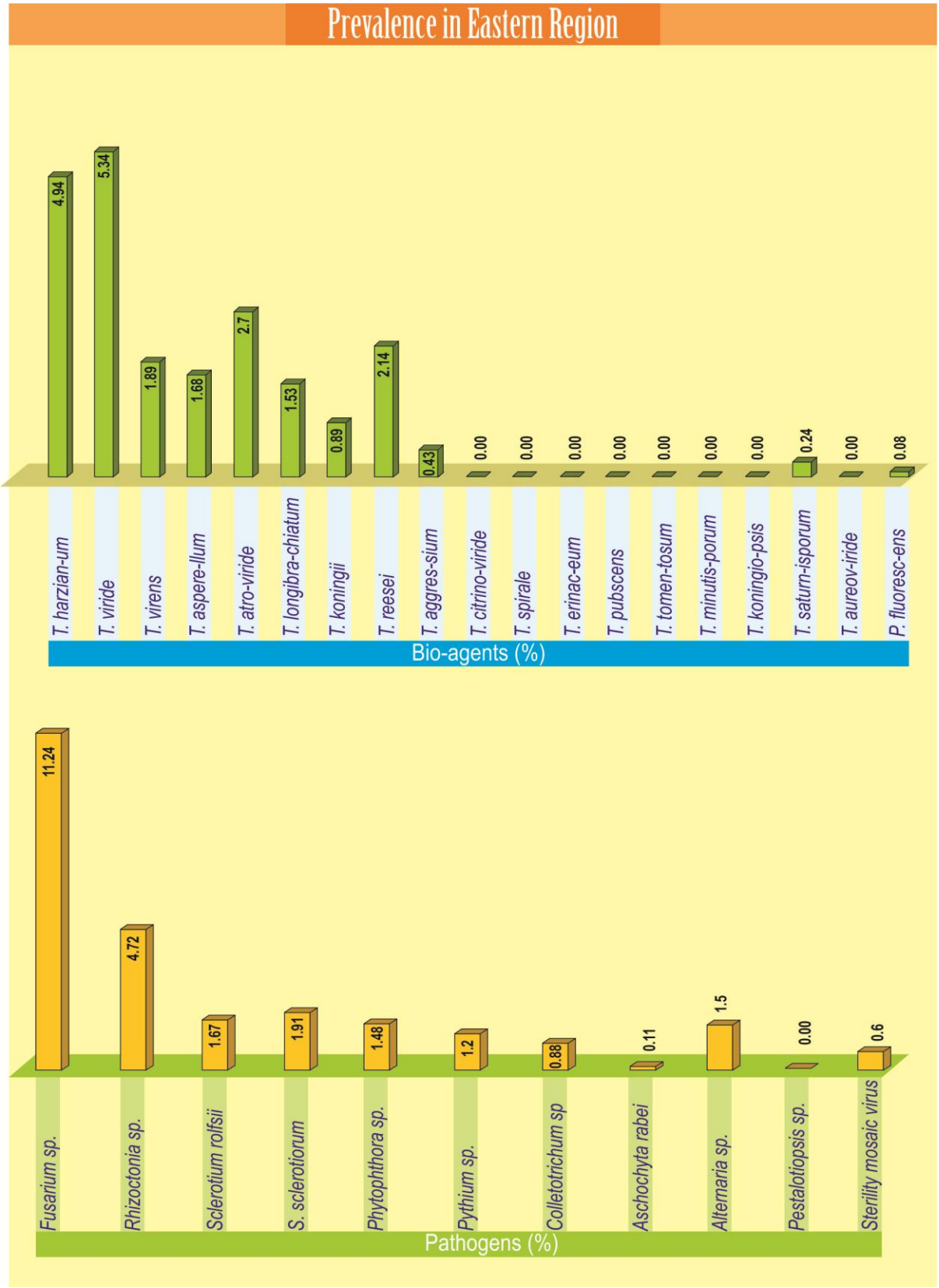
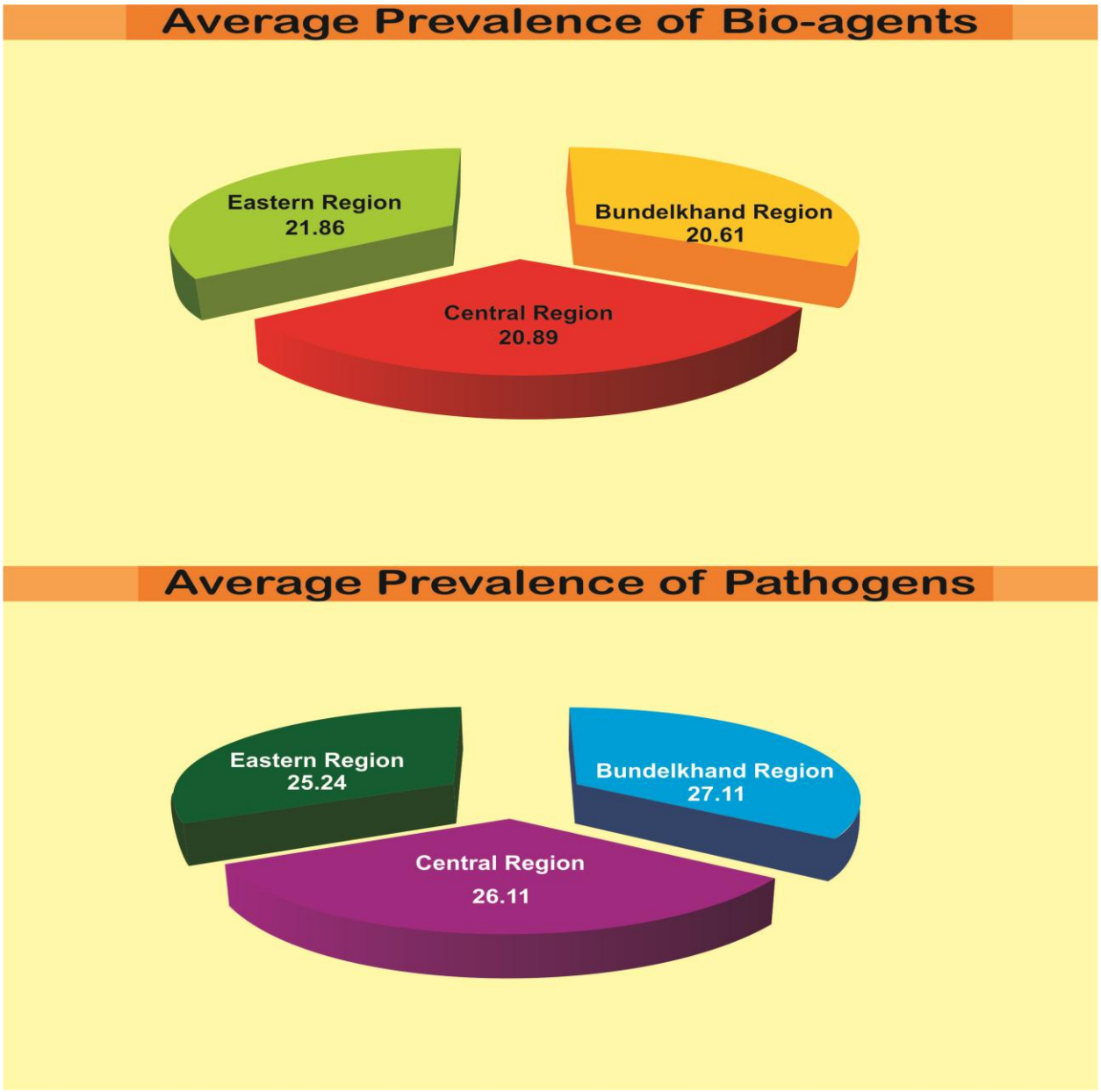


**Fig.4** Average prevalence of bioagents and phytopathogens in three agroclimatic zones of U.P.




*T. viride* has given most effective response to the pathogens while, *T. atroviride, T. reesei, T. harzianum. T. virens and T. asperellum* were given statistically same response at 5 per cent level of significance in Auraiya, Kanpur Nagar, Kanpur Dehat and Etawah.

In addition, eleven species of bioagents viz; *T. harzianum, T. viride, T. virens, T. asperellum, T.* atroviride, *T. longibrachiatum*, T. *koningii, T. ressei, T. aggrissivum, T. saturnisporum* and *Pseudomonas fluorescens* could be isolated from Eastern region of U.P. 9 species of bioagents from 9 Blocks of Allahabad; 8 species of bioagents from 6 Blocks of Sonbhadra, 7 species of bioagents from 9 Blocks of Azamgarh, 8 Blocks of Barabanki, 9 Blocks of Jaunpur, 6 Blocks of Mirzapur and 5 Blocks of Pratapgarh; 6 species of bioagents from 6 Blocks of Faizabad, 5

Blocks each of Gonda, Sant Ravi Das Nagar and 9 Blocks of Sultanpur; 5 species of bioagents from 5 Blocks each of Bahraich, Ghazipur and 6 Blocks of Varanasi. In general, 21.86 per cent bioagents were isolated from this zone.

*T. viride* and *T. harzianum* were recorded statistically at par at 5 per cent level of significance given same response towards pathogens in Mirzapur, Jaunpur, Allahabad, Bahraich and Sultanpur. *T. atroviride, T. reesei, T. virens, T. asperellum and T. longibrachiatum* were also found effective in Allahabad, Mirzapur, Jaunpur, Pratapgarh and Sant Ravidas Nagar (Fig. 1, 2 & 3).

These findings are in accordance with the findings of Tewari and Mukhopadhyay, 2001; Momol and Pernezny, 2005; Sariah *et al.*, 2005; Kumar *et al.*, 2012; Hilda *et al.*, 2012.

## Analysis of correlation between pathogen and bioagent

In case of zone wise co-efficient correlation between pathogen and bioagent it was found that in Bundelkhand region, *Fusarium* sp. were affected by *T. harzianum* and *T. asperellum*; *S. rolfsii* with *T. harzianum and T. koningii* and *Phytophthora* with *T. viride, T. asperellum* and *T. koningii.* In Central region, *Fusarium* sp. were affected by *T. atroviride*, *Rhizoctonia* sp. by *T. harzianum, T. virens, T. asperellum and T. ressei.* Similarly, *S. rolfsii* by *T. harzianum, T. viride, T. atroviride* and *T. ressei*, *Sclerotina* by *T. harzianum*, *Phytophthora* by *T. virens, T. asperellum, T. atroviride, T. koningii and T. ressei, Pythium* by *T. viride, T. asperellum, T. atroviride, T. koningii* and *T ressei*, *Colletotrichum* sp. by *T. harzianum* and *T. asperellum, Ascochyta rabei* by *T. harzianum* and *T. atroviride* and *Alternaria* sp. by *T. harzianum, T. viride, T. virens* and *T. asperellum*. It was also observed that *T. harzianum* showed negative correlation with as many as 6 fungal pathogens.

In Eastern region, *Fusarium* sp. was affected by *T. harzianum, T. virens* and *T. ressei*; *Rhizoctonia* sp. by *T. viride, T. asperellum, T. atroviride* and *T. ressei*; *S. rolfsii* by *T. harzianum, T. virens, T. atroviride* and *T ressei*; *Sclerotina* sp. by *T. virens* and *T. ressei*; *Phytophthora* sp. by *T. harzianum, T. asperellum* and *T. longibrachiatum*; *Pythium* sp. by *T. harzianum* and *T ressei*; *Alternaria* sp. by *T. harzianum, T. viride, T. asperellum, T. longibrachiatum* and *T. ressei.* It was also observed that *T. harzianum* and *T. ressei* showed negative correlation with as many as 5 fungal pathogens.

Thereby these bioagents are responsible for reduction in overall population of the pathogens in this region (Table 3, Fig. 4).

From the survey made during 2011-12 & 2012-13, it was concluded that the fields having much prevalence of bioagents showed low infestation of wilt/ root rot diseases. Based on the survey conducted in 203 blocks of 31 districts of 3 agro-climatic regions, the bioagents like *Trichoderma viride* and *Trichoderma harzianum* were prevalent in most part of the survey area of Uttar Pradesh. Other bioagents in terms of prevalence were *T. atroviride, T. ressei, T. asperellum, T. virens, T. longibrachiatum, T. koningii, T. citrinoviride, T. koningiopsis, T. aggressivum, T. aureoviride, T. erinaceum, T. pubscens, T. saturnisporum, T. tomentosum, T. minutisporum* and *T. spirale.*

Based on the survey, it was found that majority of soil borne pathogens are responsible for low yield of the pulse crops. Accidently, it was interesting to note that these soil micro-floras do harbour the bioagents, which can reduce the incidence of the disease largely.

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