

Department of Botany
FACULTY OF SCIENCE
University of Cairo
Egypt.

**RESPONSE OF SOIL MYCOFLORA TO
VARIOUS CADMIUM TREATMENTS**

A THESIS

SUBMITTED FOR THE DEGREE OF (M.Sc.)

(Botany-Microbiology)

By

Eiman Fathi Abd-El-Hamid Sharaf
B.Sc. Cairo Univ., 1977

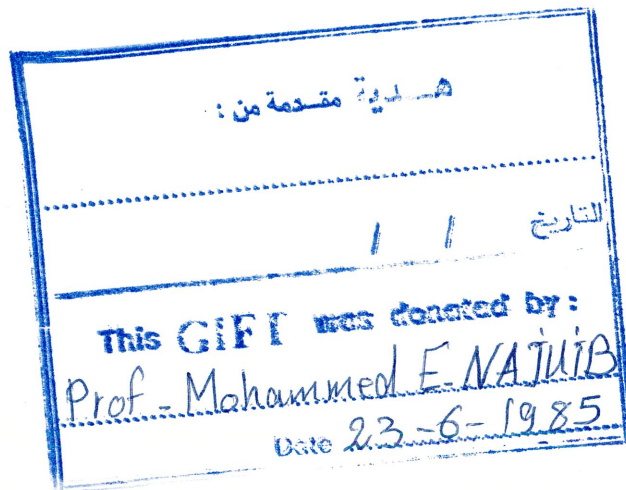
February, 1984

بسم الله الرحمن الرحيم
 الى استاذي الفاضل الدكتور محمد نجيب
 اهدي اليه هذه الرسالة مع سائل معية ليعده عن شكرى
 وامتنانى له وللمدانة الجليله - صدرته البارحة
 وذا شكره استراكم في كتابه وارجع هذه الرسالة
 تليذتكم التحلته
 ايمانه شرف



THIS THESIS HAS NOT BEEN PREVIOUSLY
 SUBMITTED FOR ANY DEGREE AT THIS OR ANY OTHER
 UNIVERSITY.

EIMAN FATHI ABD EL-HAMID SHARAF "



" DEDICATION "

TO THOSE WHO STOOD BESIDE ME
TO THOSE WHO ENCOURAGED ME TO CARRY
ON MY RESEARCH,

TO THE LOVE, SACRIFICE AND CARESS
I DEVOTE MY SELF AND MY THESIS

TO MY HUSBAND
AND MY PARENTS..

Faculty of Science
Cairo University

M.Sc. Courses
STUDIED BY EIMAN FATHI SHARAF

Beside the work presented in this thesis, the candidate has attended and passed successfully the following post-graduate courses as a partial fulfilment of the requirements for the degree of Master of Science, during the academic year 1977-1978.

1. Soil microbiology.
2. Virology.
3. Bacteriology.
4. Industrial microbiology.
5. Hydrobiology.
6. Biochemistry.
7. Biostatistics.
8. Radiation biology.
9. German (as a foreign language).

Chairman of the Botany
Department

Vice Dean

ACKNOWLEDGEMENT

The author wishes to express her sincere thanks and gratitude to Prof. Dr. M.I. NAGUIB, Professor of Plant Physiology, Botany Department, Faculty of Science, Cairo University, for suggesting the problem and supervising the research and his follow up during the preparation of the thesis.

The author is also greatly indebted to Prof. Dr. M.I. ALI, Professor of Microbiology in the same Department for his kind help in suggesting and supervising this investigation and for his continuous follow up during the lay-out of the experimental work and preparation of the thesis.

The author ~~is~~ moreover wishes to express her thanks and gratitude to Prof. Dr. M.N. EL-HADIDI, the head of Botany Department for his heartfelt help and excellent research facilities he provided.

Sincere thanks are due to Dr. I.M.K. ISMAIL, Lecturer of Microbiology in the same Department for his valuable supervision before his leave to Saudia Arabia.

The author is greatful for the help, advice and assistance offered by Dr. NAHID Z. HEIKAL Lecturer of Physiology in the same Department.

Thanks are also due to Prof. Dr. S.M. EL-KALLA Professor of Statistics, Faculty of Agricutlrue, Mansoura University for his valuable guidance in statistical analysis.

Thanks are also extended to the Colleagues and the staff members of Botany Department, Faculty of Science, Cairo University, for their sincere cooperation.

EIMAN SHARAF

C O N T E N T S

Page

PREFACE

PART I

INTRODUCTION

A)	Historical Review-----	1
B)	Material and Methods -----	9
	Plant Materials-----	9
	Treatment of cultivated soil with cadmium salts--	9
	<u>Mycological Analysis :-</u> -----	10
	Soil Plate Method-----	12
	Dilution Plate Method-----	12
	Identification of Fungi -----	13
	Preparation of Fungal cultures for spore Germination	
	Test and Biochemical Analysis -----	14
	Spore Germination Test-----	15
	Preparation of Mats-----	16
	Extraction of the Mycelium -----	16
	 <u>Chemical Analysis</u> -----	 17
	Polysaccharide Estimation-----	17
	Nitrogen Estimation -----	18
	1. Total Insoluble Nitrogen-----	18
	2. Total Soluble Nitrogen-----	19
	3. Free Ammonia -----	19
	4. Free Amino Nitrogen-----	20
	5. Peptide Nitrogen-----	20
	6. Other Soluble Nitrogen-----	20
	7. Protein-Soluble Nitrogen-----	21
	8. Non-Protein Soluble Nitrogen-----	21
	9. Other-Insoluble Nitrogen-----	21
	Phosphorus Estimation-----	21
	1. Inorganic Phosphorus-----	22
	2. Total Soluble Organic Phosphorus-----	22
	3. Total Insoluble Phosphorus-----	22
	Organic Acid Assay-----	23

PART II

EXPERIMENTAL RESULTS

A)	Effect of Cadmium Sulphate and Cadmium Nitrate on Rhizosphere Fungi of <u>Glycine Max</u> and <u>Zea Mays</u> Plants	25
	a. Frequency of occurrence -----	29
	b. Effect of Cadmium Salts-----	38

	<u>Page</u>
B) Effect of Cadmium Salts on some Growth Criteria of Representative Fungi from the Rhizosphere of <u>Glycine Max</u> and <u>Zea Mays</u> -----	41
Spore Germination-----	42
Mycelial Dry Weight -----	45
Nitrogen Secretion-----	48
Nitrogen Components of Biomass -----	51
Phosphorus Components of Biomass-----	54
Total Polysaccharide content-----	57
Organic Acid Secretion-----	58

PART III

A) DISCUSSION -----	62
B) SUMMARY-----	82
C) REFERENCES -----	85
D) APPENDIX -----	i

ARABIC SUMMARY :

PREFACE

Cadmium as an environmental pollutant, stimulated researches in biology. Industrial activities viz. cement or metal smelting plantations, mining, biocides, fertilizers, sewage disposal and automobile traffic are the main sources of cadmium pollution. The entry of this cadmium into plants, is currently of concern, since it may eventually affect human health.

The present investigation aims at the evaluation of the effect of some cadmium salts on the prevalence of rhizosphere fungal flora of soybean and corn. Parallel experiments were also undertaken to find out possible explanations, for the observed variations in microfloras in terms of sensitivity or tolerance of these microorganisms to cadmium ion, through the study of some growth criteria of some selected fungi isolated from the rhizospheres under cadmium stress.

PART I

I N T R O D U C T I O N

- A) HISTORICAL REVIEW
- B) MATERIAL AND METHODS

PART I INTRODUCTION

A) HISTRIOCAL REVIEW

Cadmium, as one of the most hazardous environmental pollutants, gained a world-wide attention not only by government authorities, but also by scientists in different fields of research, who were asked to provide a clue for the harmful effects of cadmium towards living organisms. An increasing number of publications has already proved the accumulation of cadmium in microorganisms, higher plants and animals as a result of pollution and of increasing cadmium concentrations in soils and surface water.

Cadmium passes to the soil from different sources. Its essentiality to plants or animals has not yet been clearly established, but its accumulation at high levels is very toxic (Hewitt, 1953; Page et al., 1972; Miller et al., 1973). The effects of heavy metals on fungal cells have long been of interest to mycologists as a result of their value as fungicides. Several studies has been dedicated to the potentialities of heavy metals as inhibitors for spore germination but relatively less attention has been directed to matters of transport into fungal cells and effects on metabolism. Many fungi can adapt to resist heavy metals (Ashida, 1965; Turner, 1969) and in recent years resistance to heavy metals has arisen under

high tolerance to cadmium and thus were able to grow on media containing 10,000 ppm, of the metal. The same authors reported that cadmium resistant fungi were also resistant to copper. Accordingly the mechanism of tolerance to both elements seemed to follow the same routes. Similar observation was reported by Lillehoj et al., (1974) and Marsh et al., (1975).

Babich and Stotzky (1977,a) noted wide extremes in sensitivity to cadmium among fungi. There was no correlation between the class of fungus and tolerance to cadmium. Tatsuyama et al., (1975, c) found that Penicillium lilacinum was strongly resistant to zinc, copper, tin and cadmium whereas P. purpurogenum showed resistance to cadmium and copper only. They observed that ED_{50} of the heavy metals, tested on conidial germination of P. lilacinum, were different from those on mycelial growth. Babich and Stotzky (loc. cit.) reported that fungal sporulation was more sensitive to cadmium than mycelial growth, since spore formation was inhibited at cadmium levels that were not inhibitory to mycelial proliferation.

Ernst (1972) observed air-borne zinc and cadmium particles which decreased the vitality of higher plants and the activity of microorganisms, in the vicinity of a zinc smelting plants.

Gingell et al., (1976), using a leaf-washing method, showed that the microflora of zinc, lead and cadmium contaminated

plants around a smelter was low in abundance and species diversity. They also found that, in artificial media, the isolates from such plants were more tolerant to heavy metals than the isolates from uncontaminated plants. The counts of Cladosporium herbarum, Aspergillus niger, Erysiphe graminis, Botrytis cinerea and Diplocarpon rosae were low but the pigmented yeasts and bacteria seemed to be very sensitive to the metals.

Byrne et al., (1976) surveyed the concentration of 10 trace elements in about 27 of higher fungi isolated from several sites. They recorded high levels of mercury in many species but cadmium accumulated to a surprising extent by most fungi; its average value being 5ppm. The same authors stated that " as well as these features are of biochemical interest, the values found and the pattern of accumulation suggest potential uses of fungi in environmental studies". A cadmium resistant yeast strain which might be used to remove cadmium from industrial waste water containing cadmium was isolated by Tohoyama and Murayama (1977). Houba and Remacle (1980) showed that some bacteria developed in very high concentrations of cadmium but their physiological characteristics were not the same as those of the sensitive strains.

Croessmann and Egels (1975), in their studies on 633 single commercial feedstuffs, found that about one third of

the investigated samples were contaminated with cadmium. They reported that the cadmium contaminations were air-borne from industry, burning oil and coal as well as during the production and manufacturing of feedstuffs themselves.

A metal may be regarded as toxic if it impairs growth or metabolism of an organism above a certain concentration. In fact all elements may be toxic when administered at high concentrations whereas other viz. mercury or copper (essential at trace levels) were toxic at relatively low concentrations. Some metals apparently act at the cell membrane causing changes in permeability. These include gold, cadmium, copper, mercury, lead and uranium (Passow et al., 1961).

It has not been determined whether all the trace elements required for normal growth by higher plants are essential to cryptogams. There is no evidence, however, to suggest that the basic metabolic processes of cryptogams are fundamentally different from those of higher plants or non-lichenized fungi and algae.

Data is accumulating regarding the effect of heavy metals on growth and metabolism of microorganisms. Thus Lobyreva (1973) recorded that addition of metal ions (Fe^{3+} , Mg^{2+} , Mn^{2+} , Zn^{2+} , Ni^{2+} , Ba^{2+} , Co^{2+} , Cd^{2+} , Ca^{2+} and Cu^{2+}) to the reaction medium stimulated lipase and lipolytic action of the yeast Candida utilis 295t.

Lillehoj et al., (1974) reported that the aflatoxin elaboration by Aspergillus flavus was reduced by 25 ug cadmium, 500 ug copper per g. Marsh et al., (1975) concluded that four of the more potent metals (copper, cadmium, silver, mercury) in inhibition of aflatoxin production were also fungicidal at high concentrations. The ability of each of these four metals to react with sulfhydryl groups (-SH), was suggested as a cause of their fungicidal action (Martin, 1969).

It has been postulated that cadmium caused a direct inhibition of alkaline as well as acid phosphatase activities in lower organisms, because of the interaction of cadmium with intercellular protein (Uchida et al., 1973). Pickett and Dean (1976) showed that strains of Klebsiella aerogenes resisted such inhibition when treated with 50 ug cd/ml.

Cenci and Morozzi (1977) studied the effect of Cd^{2+} and $\text{cd}(\text{CN})_4^{2-}$ ions on growth and enzymic activity of mixed microflora from activated sludges. They revealed that both ions significantly inhibited growth of microorganisms and that the inhibitory effect of Cd^{2+} was significantly greater than that of $\text{Cd}(\text{CN})_4^{2-}$ at the same mass and molar concentrations. Brown and Smith (1980) claimed that the generative time of the yeast Cryptococcus albidus was increased 3-fold when cultures were supplemented with 10 mg/L. Cd^{2+} and the cell division of that yeast was arrested at concentration above 50 mg/L.

The effect of cadmium on nucleic acid metabolism and/or protein synthesis recieved little or no attention, though a good deal of vital activities depended entirely on enzymatic proteins. The capture of cadmium within binding sites of proteinic nature, in plants and animals is now established by several investigators. Squibb and Cousins (1974), Sabbioni and Marafante (1975) suggested that cadmium stimulated the formation of a denovo cadmium-binding protein in rat liver. Similarly cadmium-binding proteins were detected in plant tissues following treatment with the metal (Malone et al., 1978; Petit, et al., 1978; Bartolf et al., (1980). An earlier study by Dekock (1956) suggested that the major effect of the toxic metal was manifested in the root where it combined with some protein chelates. The metal competed for and displaced iron from active chelating centers; a phenomenon already confirmed by Malone et al., (1978).

Stoll et al., (1976) found that cadmium significantly inhibited RNA synthesis in rat liver nuclei and decreased DNA in hepatectomized rat. It seems that cadmium directly interacted with the DNA synthesis.

Imagawa et al., (1981) observed that growth of Bacillus megaterium was inhibited by $> 5\mu\text{M}$ cadmium chloride but the cells couldn't grow at $50\ \mu\text{M}$ concentration. They also reported that

that the greater part of cadmium was bound to protein whose molecular weights were more than 200,000 and the activity of phosphoglycerate mutase was higher in cadmium-free than cadmium-fed cells. There may be some relationships among decreased manganese content of cells, phosphoglycerate mutase activity and inhibition of cell growth by cadmium chloride.

It is now well established that cadmium is toxic to animals causing erythrocyte destruction, testicular damage, renal degradation and hypertensive heart disease (Perry et al., 1961 ; Schroeder and Balassa, 1961; Schroeder, 1965; Perry, 1968; Lagerwerff, 1972). A good correlation between cardiovascular death rates and concentration of cadmium in air as an industrial pollutant was reported by Carroll (1966). It may induce malignant tumors in rats (Gunn et al., 1963). Cadmium binds with low molecular weight protein in liver and kidney (Shaikh and Lucis, 1970; Nordberg and Piscator, 1971 ; Nordberg et al., 1972; Webb, 1972; Winge and Rajagopalan, 1972; Cousins et al., 1973; Squibb and Cousins, 1973). The high affinity of cadmium for the-SH group in a number of zinc-containing enzymes seemed to be responsible for its toxicity to guinea pigs (Chueca et al., 1971).

B MATERIAL AND METHODS

Plant Materials :

During a green house sowing, in 1981, the author studied the effect of cadmium sulphate and cadmium nitrate on the rhizosphere fungi of a leguminous plant Glycine max L. (Soybean, cultivar, 71) and a monocotyledonous plant Zea mays L. (dihybrid, 186). Seeds and grains of the plants were kindly supplied by the Plant Breeding section of ARE Ministry of Agriculture.

Treatment of Cultivated Soil With Cadmium Salts, :

Through this investigation, experiments were carried out using sandy-clay soil with pH 7.1 , 0.4% organic matter content and 0.34% total soluble salts (Jackson, 1967).

About 150 Kilogram of air dry sieved soil was placed in wooden boxes (50 x 50 x 50 cm) in which the seeds or grains were sown. The water content of the soil was adjusted to 40% water holding capacity to permit good aeration. The method used for such adjustment of the soil water content was as follows :

One sample of the top four inches of soil was removed at each of four points in each box using a tubular sampler.

These soil cores were thoroughly mixed and then divided into four portions and the moisture content was determined for each portion on an oven dry basis by the standard procedure. The results were expressed as percentage of the maximum water holding capacity which was determined by the keen and Raczkowski (1921) perforated box method (Helgar's pan method) as perfected by Garrett (1946). Cadmium, as sulphate and nitrate, was applied to the soil at 100, 500, 1000, and 2000 ppm concentration. Four replicate of boxes represented one treatment including the cadmium-free controls. Soil samples were collected from the root zones of plants raised under the various experimental conditions (usually at a distance of 4-8cm. from the root and at a depth of 5-12 in the soil) with sterilized spoons, mixed thoroughly and kept in sterilized containers for further use.

Four samples were taken at random from each box. These were brought together into one composite sample which was thoroughly mixed. Finally 10 gm (calculated on oven dry basis) of the mixed composite sample were used for determining the frequency of occurrence of the various genera and species of fungi by the dilution plate method.

Mycological Analysis :

A preliminary trial was carried out to compare the

dilution plate method and the soil plate method (Warcup, 1950) for isolation of the fungal genera and species from the soil. Three different media, were used to choose the most suitable for growing the inocula. These were as follows :

Potato-dextrose agar (Riker and Riker, 1936) :

Agar	20 g.
Potato mush	200 g.
Dextrose	20 g.
Distilled water	1000 ml.

Czapek-Dox agar (Thom and Raper, 1945) :

Agar	15.00 g.
sodium nitrate	2.00 g.
Dipotassium hydrogen phosphate.	1.00 g.
Magnesium sulphate	0.50 g.
Potassium chloride	0.50 g.
Ferrous sulphate	0.01 g.
Sucrose	30.00 g.
Distilled water	1000.0 ml.

Peptone-dextrose agar (Martin, 1950 ; Johnson, 1957):

Agar	20.0 g
Potassium dihydrogen phosphate	1.0 g.
Magnesium sulphate	0.5 g.
Peptone	5.0 g.
Dextrose	10.0 g.
Distilled water	1000.0 ml
Rose bengal	1:30,000
Streptomycin or Aureomycin	30 ug/ml.
	2 ug / ml.

The first two media supported vigorous growth of some fungi as well as bacteria which disturbed the counts and

types of fungi arising on the plates. Accordingly they were discarded and the third medium (Peptone-dextrose agar with streptomycin) was used.

Soil Plate Method :

This was designed by Warcup (1950) in order to reduce some of the particular disadvantages from which the soil dilution plate suffered. In this method, very small samples (0.005-0.015 g) of soil were taken with the flattened blade of a sterilized nichrome inoculating needle, into the bottom of a sterile Petri-dish ; a little sterile water (1 ml) is added to assist in the dispersion of soils that don't break up easily. Melted and cooled agar (10-15 ml) was then poured into the dish and swirled before setting in order to secure complete dispersion of the soil particles.

Dilution Plate Method : " Johnson et al., 1960"

10 g soil sample was suspended in 90 ml. sterile distilled water and shaken on a mechanical shaker for about 20 minutes. One ml. of this suspension was aseptically withdrawn (while in motion) and transferred into 99 ml. sterile distilled water. One ml. portions of such dilution was smeared on molten agar. The dishes, containing such media, were gently shaken in a broad swirling motion, to spread the agar medium evenly. All dishes

were incubated at 27°C for 7 days. The number of colonies developing on each dish was counted after 48 hours incubation then after 7 days to record the relative abundance of the main types of fungi. The average number of colonies per dish was multiplied by the dilution factor to obtain the number per gram original soil sample.

At least 5 replicate dishes were used for each sample. The preliminary trials to compare the above mentioned two methods of count and isolation revealed that intercolony competition was more severe on the soil plate than on the dilution plate method. A similar result was reported by Garrett (1963). Due to this disadvantage, the dilution plate method was preferred and adopted during this work.

Identification of Fungi :

The fungal colonies arising on the plates were examined and the fungi were identified to genera and species by microscopic examination. Some fungal colonies which failed to sporulate on the adopted medium (peptone dextrose agar) or after transference to other types of media were classed as *Mycelia sterilia*. A list of the fungi isolated during this work is included in the appendix.

The identification of fungal genera and species was made through the help of the following references :

- 1) Ames (1969) for Chaetomium species.
- 2) Barnett and Hunter (1972) for the genera of imperfect fungi.
- 3) Barron (1968) for the genera of Hyphomycetes.
- 4) Booth (1977) for Fusarium species.
- 5) Brown and Smith (1957) for Paecilomyces species.
- 6) Ellis (1971 and 1976) for Dematiaceous Hyphomycetes.
- 7) Gilman (1957) for soil fungi in general.
- 8) Raper and Fennell (1965) for Asperigillus species.
- 9) Raper and Thom (1949) for the species of Penicillium and P. related genera.

Statistical analysis, for each fungal group, were carried out according to analysis of variance in Factorial analysis for two salts (CdSO_4 and $\text{Cd}(\text{NO}_3)_2$), five concentrations (0,100,500,1000 and 2000 ppm) for two types of plants. To ascertain the differences between means L.S.D. (Least significant difference) at 1% and 5% were used (Snedecor and Cochran, 1966).

Preparation of Fungal cultures for Spore Germination Tests And Biochemical Analysis :

Asperigillus terreus, Cladosporium herbarum, Rhizopus oryzae, Curvularia tetramera, Fusarium oxysporum and Paecilomyces divaricata were used in the study of the effect of

the two cadmium salts on spore germination, growth and biochemical changes that may occur.

Spore Germination Test :

14 plates (9 cm diameter) were used for each fungal species. Two plates contained a thin layer of Czapek Dox medium (about 10 ml/ plate) for control (non treated medium) and the other 12 plates contained Dox medium supplemented with 50, 100, 1000 ppm cadmium sulphate or cadmium nitrate. Each plate was divided into areas of approximately 1 cm². On each agar square a drop of spore suspension from 7 days old culture slant was placed. The spore suspension was carefully prepared to give drops containing a moderate density of spore (25-30 spore in the microscope field). The plates were then incubated at 25-27°C and examined for the percentage germination at intervals which varied according to fungal species.

Preliminary trials were made to determine the least incubation period to allow for 50% germination of the control spore suspension. Such interval was taken as the time limit before examining the treated plates to determine the percent of their germination. Four blocks of the Dox agar medium were removed, stained with cotton blue in lactic

acid and 4 microscopic fields per block were examined for their content of germinated spores as well as germ tube length (i.e 16 readings for each treatment). Results were expressed as percentage of control. Further examination, after larger periods of incubation was performed in order to find out whether the lagging germination was temporary or permanent.

Preparation of Mats :

For each fungus 14 conical flasks (250 ml.capacity) each containing 50 ml.Dox liquid media were used. Triplicate flasks served as controls or experimental where Dox's liquid media was amended with 50, 100, 500, or 1000 ppm cadmium sulphate or nitrate. The flasks were inoculated with a 5mm diameter agar disc from the periphery of 7 days old culture plates. The flasks were incubated at 25-27°C for 7 days after which the produced mycelial felts were collected, washed several times with distilled water and oven-dried at 80°C till constant weight. The dried mats were then finely powdered, kept in a desiccator for further analysis.

Extraction of The Mycelium :

50 mg of the dry mycelial samples were extracted by addition of 10 ml.borate buffer, at pH 8. The mixture

was left standing overnight before centrifugation. The residue was dried at 80°C while the filtrate was made up to 50 ml. and kept in a refrigerator. Equal volumes of the fungal extract and 15% trichloroacetic acid were mixed to ensure precipitation of soluble peptides then centrifuged to eliminate the interference of this nitrogen component during chemical analysis.

Chemical Analysis :

The fungal mats as well as their media were analysed for the nitrogen, phosphorus and polysaccharide content.

All analysis were carried out on unacidified extracts or media except for the amino nitrogen and inorganic phosphorus where soluble peptides must be removed by acidification. The insoluble nitrogen and phosphorus components and polysaccharides were estimated in the residue after filtration of the extract.

Polysaccharide Estimation :

20 mg of the dry residue were hydrolysed by 5 ml. 1.5 N sulphuric acid for two hours in a boiling water bath. After neutralization to phenol red, they were further mixed with 3 ml. basic lead acetate (13.7 gm per liter)

and filtered on 3 ml. sodium dihydrogen phosphate (119 gm per liter to which was added 1 ml. concentrated sulphuric acid; C.f., Said and Naguib, 1964). Another filtration was necessary, to remove the excess precipitated lead, before making up the solution to a known volume ready for analysis. 2 ml cleared neutralized solution were thoroughly mixed with 2 ml. modified Nelson's solution (Naguib, 1964). The mixture was kept in boiling water bath for 15 minutes before rapidly cooled in running tap water. 2 ml arsenomolybdate solution (Nelson , 1944) were added and the mixture was shaken till efferevescence stopped. The coloured solution was diluted to the appropriate intensity before photometrically measured at 700 nm.

Nitrogen Estimation :

The procedures followed in this investigation, were majorly quoted from the article presented by Naguib, (1969):

1. Total Insoluble Nitrogen :

About 20 mgm. of the dry residue, after centrifugation, were wet digested using 50 % sulphuric acid followed by little dilute perchloric acid, for completion of oxidation. This was made up to volume before a known

aliquot was neutralized and its ammonia content was estimated by Berthelot reaction.

2. Total soluble Nitrogen :

The above mentioned procedure was repeated on few mls. of the borate buffer extract.

The values obtained by this procedure denoted all soluble nitrogen components but nitrate and nitrite which should be considered in order to obtain the true estimate of all the soluble nitrogen components.

3. Free Ammonia :

A known aliquot of the borate extract was neutralized before the direct estimation of its ammonia-content using Berthelot reaction.

The procedures mentioned by Fawcett and Scott(1960) and Chaney and Marbach (1962) were followed in this investigation. 1ml. 5% phenol containing 25 mgm. sodium nitroprusside, was added to a known volume of the neutral extract followed by 1 ml of 2% sodium hypochlorite dissolved in 0.63 N sodium hydroxide. The mixture was incubated at 37°C, for 15 minutes, diluted to a known volume and the optical density was determined at 630 nm.

4. Free Amino Nitrogen :

A protein free sample was made slightly alkaline to phenolphthalin before addition of 1 ml. 1% borax (Russell, 1944). After shaking, another 1 ml. 0.25% freshly prepared naphthoquinone-sulphonic acid was added. The mixture was kept in boiling water bath for 15 minutes then rapidly cooled. Acid formaline and thiosulphate solutions were added and the shaken mixture stood 20 minutes before estimation of its colour intensity at 470 nm.

5. Peptide Nitrogen :

The procedures of Lowry et al., (1951) were followed. A sample of the borate extract was mixed with 1 ml. freshly mixed in (1:1 ratio) solution of 2% sodium carbonate in 4% sodium hydroxide and 0.5% copper sulphate in 1% sodium tartrate. The mixture stood 10 minutes before addition of 0.1 ml. Folin phenol and made up to volume. The optical density of the mixture was measured, after 30 minutes, at 700 nm.

6. Other soluble Nitrogen :

If we subtract the product of peptide, amino and ammonia nitrogen from the value, obtained experimentally for the total soluble nitrogen (item, 2 ,pl9) we can calculate the value of the other nitrogen including the amide and acyclic forms (purines and pyrimidines).

7. Protein-soluble Nitrogen :

The known quantity of dry residue, after filtration, was dissolved in a defined volume of 4% sodium hydroxide and kept standing overnight, at 25°C before centrifugation. A known aliquot of the centrifugate was analysed for its protein-soluble nitrogen using the folin-phenol procedure (item 5 , p20).

8. Non-Protein Soluble Nitrogen :

A known volume of the sodium hydroxide centrifugate (item 7, p 21) was digested and its total nitrogen content was determined, following the procedures already mentioned (in item 2, p 19). If we subtract the value of protein soluble nitrogen from that obtained by this procedure we calculate the non-protein soluble nitrogen component.

9. Other Insoluble Nitrogen :

If we subtract the value obtained by the previous procedure (item 8, p 21) from that already determined for the total insoluble nitrogen (item 1, p 18) the value of the other insoluble nitrogen can easily be calculated.

Phosphorus Estimation :

The sulphite-metol method, adopted by Burton and Riley (1954) was used in this investigation. All estimations were carried out on neutral samples, using phenolphthalein as indicator.

1. Inorganic Phosphorus :

A known volume of TCA-acidified extract was neutralized then 1 ml. 2.5% freshly prepared ammonium molybdate and 0.5 ml. of 10 N. sulphuric acid were added. The mixture was shaken and kept standing for 15 minutes before addition of 2 ml. sulphite-metol reagent. The mixture was diluted to the appropriate volume and its optical density was measured at 700 nm, after 20 minutes standing.

2. Total Soluble Organic Phosphorus :

A known aliquot of the digest for total soluble nitrogen (item 2, p 19) was withdrawn for the assay of its phosphorus content. If we subtract the value of inorganic phosphorus from that recorded for this procedure, we get the value of total soluble organic phosphorus.

3. Total Insoluble Phosphorus :

A known volume of digested sodium hydroxide residue solution (item 8, p 21) was neutralized before its phosphorus content was assayed.

Organic Acid Assay :

5ml. of the filtered culture media were titrated against 10^{-3} N sulphuric acid using a dilute acid indicator.

The acid indicator (Ahmed and Ries, 1969) was composed of a mixture (in 9:1 ratio) of 0.075 gm bromocresol green + 0.025 gm bromophenol blue in 150 ml. absolute alcohol, and 0.25 gm potassium permanganate + 0.5 gm sodium carbonate in 150 ml. water. In presence of relatively low acid concentration the indicator had to be diluted to half concentration.

Parallel blank titrations were carried out using the initial liquid culture media.

PART II
EXPERIMENTAL RESULTS

A, EFFECT OF CADMIUM SULPHATE AND CADMIUM NITRATE
ON RHIZOSPHERE FUNGI OF GYLCINE MAX AND ZEA
MAYS PLANTS

This experiment was designed in order to investigate the influence of cadmium sulphate and cadmium nitrate over 4 dosage range, on the ability of fungi to survive in the rhizosphere of two main crop plants namely soy bean (Glycine max L.=A) and corn (Zea mays L.=B).

Soil samples were monthly collected, from the root zone of the test plants grown under the previously reported experimental conditions(C.f.p. 9 of this dissertation). The samples were collected at a distance of 4-8cm far from the roots and at a depth of 5-12 cm in the soil, dependent on the size of the root system. Samples were collected with sterilized spoons then thoroughly mixed. Three to five samples were taken, at random, from each box of each treatment. Accordingly we obtained four composite samples for each treatment. Ten grams (calculated on oven dry basis) of each sample were used to determine the frequency of occurrence of the genera and species of fungi applying the dilution plate method (Johnson et al., 1960).

Table 1 records the frequency of fungi insolated from rhizosphere and control sample obtained under the various experimental treatments. Statistical analysis of the results (Table 2) show that :

1. Both cadmium salts were toxic (at the four doses,)to the total count of rhizosphere fungi of the two plants (A and B) after the different experimental periods.
2. Cadmium sulphate doses were more inhibitory or deleterious than cadmium nitrate (total count 38182 and 43431 respectively).
3. The nature and type of test plant had a prominent effect on the total count of its rhizosphere fungi. Soy bean supported statistically lower total counts in its rhizosphere than corn; the total count being 38767 and 42846 respectively.
4. Increasing the concentration of either cadmium salts favoured a lower total count of rhizosphere fungi, especially at 1000 and 2000 ppm, when compared with the untreated controls. This results is quite obvious from the following tabulation :

Treat- ment.	Control	Doses ppm			
		100	500	1000	2000
CdSO ₄	13508	11260	11224	7578	8120
Cd(NO ₃) ₂	13852	12194	11133	10180	9924

Table 1 : Frequency of fungi isolated from rhizosphere and control samples under the various experimental conditions
(presented as total isolation during each experimental period).

Treatment	1st isolation				2nd isolation				3rd isolation				4th isolation				5th isolation			
	CdSO ₄		Cd(NO ₃) ₂		CdSO ₄		Cd(NO ₃) ₂		CdSO ₄		Cd(NO ₃) ₂		CdSO ₄		Cd(NO ₃) ₂		Cd SO ₄		Cd(NO ₃) ₂	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
0 Control	520	400	520	400	1814	1264	1814	1264	1799	2103	1799	2103	1241	1599	1241	1599	1380	1560	1380	1560
100	940	997	520	667	736	1109	1416	1278	1132	934	1042	1002	1094	1425	1418	1550	1643	1250	1786	1515
500	600	580	820	740	732	948	1242	836	1087	1114	1199	1110	1782	1918	1075	1302	1355	1108	1412	1397
1000	120	240	860	460	722	1031	380	820	590	1601	900	1932	889	565	1040	1561	636	1184	940	1287
2000	260	540	735	720	601	610	429	908	555	811	1065	1088	1688	1201	985	1510	800	1054	1541	943

A = Glycine max (soybean)

B = Zea mays (corn)

Table 2: Average numbers of the total counts of fungi as affected by the two cadmium salts, different concentrations, the two plants Glycine max (A) and Zea mays (B) and the date of isolations.

Source of variance	Averages
Salts	
CdSO ₄	1037.24
Cd(NO ₃) ₂	1142.22
F test	-
Concentrations (ppm)	
0	1368.00
100	1172.70
500	1117.85
1000	887.90
2000	902.20
F test	**
LSD 5%	169.83
LSD 1%	225.02
Plant	
A	1045.50
B	1133.96
F test	-
Date of isolation	
22.7.1980	581.95
20.8.1980	997.70
22.9.1980	1248.30
22.10.1980	1334.15
20.11.1980	1286.55
F test	**
LSD 5%	169.83
LSD 1%	225.02

- Non significant
 * Significant
 ** Highly significant.

Table 3 represents the percentage frequency of occurrence of the rhizospheric fungi(as groups)isolated under the different experimental conditions. The data in this table were deduced from table (a-e) of the appendix. Statistical analysis of these data (Table 4-8) reveal the following :

a) Frequency of Occurrence :

1. Aspergilli represented the group of fungi of highest frequency of occurrence under the various experimental conditions, met with in this investigation. Fungi belonging to this group represents 47.2-50.7% of the total isolations with an average of $49.0\% \pm 1.8$. This group was represented by the single genus Aspergillus including 11 species comprising almost half the total number of isolations of the rhizosphere fungi.

Aspergillus niger, A. terreus, A. ochraceus, A. flavus and A. ustus were the main dominant species of this group, under the various experimental conditions. The rest of the species, were less frequent namely A. Clavatus A. humicola, A. parasiticus, A. sulphureus, A. sydowi and A. candidus.

A.niger was the most dominant organism as could be observed from the highly statistically significant difference

Table 3 : Frequency of occurrence of fungal groups isolated from rhizosphere and control samples under the various experimental conditions (presented as percentage isolation during the experimental period).

Fungal groups	% of total isolation						Number of genera	Number of species
	Control		Cd SO4		Cd(NO3)2			
	A	B	A	B	A	B		
<u>Aspergillus</u>	51.70	59.00	48.00	47.21	50.71	50.16	1	11
<u>Moniliaceae</u>	13.62	25.63	11.20	23.16	12.82	27.66	7	8
<u>Phycomycetes</u>	3.85	8.56	11.15	11.28	10.77	10.79	3	6
<u>Dematiaceae</u>	5.76	1.52	9.01	3.43	8.82	4.63	8	10
<u>Mycelia sterilia</u>	9.64	0.57	6.07	2.36	4.74	2.09	3	3
<u>Ascomycetes</u>	6.44	3.54	6.10	8.55	4.27	2.05	3	3
<u>Fusarium</u>	7.02	-	7.00	0.46	4.63	0.37	1	2
<u>Penicillium</u>	1.97	1.18	1.30	4.00	3.00	2.34	1	4
Total	100.00	100.00	99.83	100.46	99.76	100.09	27	47

A = Glycine max (Soy bean)

B = Zea mays (Corn)

Table 4 : Average numbers of the group Aspergillus as affected by the two cadmium salts, different concentrations and the two plants Glycine max (A) and Zea mays (B).

Source of variance		Date of isolation				
		22-7-1980	20-8-1980	22-9-1980	22-10-1980	20-11-1980
Average number						
Salts						
Cd(SO ₄)		380.90	670.40	602.70	542.00	419.20
Cd(NO ₃) ₂		499.75	759.75	717.50	562.20	407.25
F test		-	-	**	-	-
Concentrations(ppm)						
0		340.00	1169.00	1196.50	493.00	590.00
100		630.75	900.00	476.75	572.50	429.00
500		504.75	719.00	610.25	665.50	442.50
1000		305.00	434.50	667.50	554.00	378.50
2000		421.25	353.00	349.50	475.50	226.25
F test		-	*	**	-	**
LSD 5%			387.17	99.32		125.57
LSD 1%				164.34		207.78
Plant						
A		438.40	738.90	615.30	449.25	379.40
B		442.25	689.25	704.90	654.90	447.10
F test		-	-	*	*	-

in its number and percentage isolation compared with all species of fungi isolated during this investigation.

2. Moniliaceae (excluding the two genera Aspergillus and Penicillium) came second in the order frequency of occurrence. This group represented 11.2-27.7% of the total isolation with an average of $18.7\% \pm 8.23$. It was represented by 7 genera comprising 8 species. Paecilomyces silvatica, P. divaricata and Cephalosporium curtisii were commonly met with but Trichoderma koningii, Aureobasidium pullularia, Verticillium candelabrum, Candida albicans and Arthrobotrys oligospora were rather scarcely spotted on the isolation plates.

3. Fungi belonging to Phycomycetes came in the third rank of frequency, representing 10.8-11.3% of the total isolations with an average of $11.0\% \pm 0.25$. Three genera including six species were isolated. Rhizopus oryzae, the main fungus in this group appeared almost in all isolation plates. Mucor silvaticus, Cunninghamella echinulata, Mucor jensenii, M. corticolus, M. varians and M.sp. were of rare occurrence.

4. Fungi belonging to Dematiaceae represented 3.4-9.0% of the total population of fungi with an average of $6.5\% \pm 2.79$. This group was represented by 8 genera comprising 10 species. Curvularia tetramera, Humicola brevis

Table 5 : Average numbers of the group Moniliaceae as affected by the two cadmium salts, different concentrations and the two plants Glycine max (A) and Zea mays (B).

Source of variance		Date of isolation			
Average number		20-8-1980	22-9-1980	22-10-1980	20-11-1980
Salts					
CdSO ₄		86.75	148.00	382.70	303.70
Cd(NO ₃) ₂		91.30	226.60	362.50	453.40
F test		-	-	-	-
Concentration (ppm)					
0		180.00	275.50	492.00	390.00
100		47.50	101.25	363.75	565.75
500		63.25	135.25	413.75	339.75
1000		83.50	227.75	175.25	214.00
2000		71.00	196.75	418.25	383.50
F test		-	-	-	-
Plant					
A		81.00	102.20	233.90	226.40
B		97.10	272.40	511.25	530.75
F test		-	**	-	*

Table 6 : Average numbers of the group Phycomycetes as affected by the two cadmium salts, different concentrations and the two plants Glycine max (A) and Zea mays (B).

Source of variance		Date of isolation			
Average number		22-7-1980	20-8-1980	22-9-1980	22-10-1980 20-11-1980
Salts					
Cd(SO ₄)		88.75	99.10	95.50	90.00 120.40
Cd(NO ₃) ₂		75.10	127.50	96.90	126.70 122.25
F test		-	-	-	-
Concentration(ppm)					
0		100.00	180.00	41.00	55.50 50.00
100		88.00	118.75	118.25	110.00 131.00
500		81.25	84.00	111.25	139.25 147.50
1000		100.00	112.75	116.25	133.50 122.00
2000		40.50	71.00	94.25	103.50 156.25
F test		-	-	*	-
LSD 5%				32.50	
Plant					
A		88.70	106.10	88.70	102.60 69.20
B		75.20	120.50	103.70	114.10 173.50
F test		-	-	-	**

Table 7 : Average numbers of the group Dematiaceae as affected by the two cadmium salts, different concentrations and the two plants Glycine max (A) and Zea mays (B).

Source of variance	Date of isolation	
	Average number	
	22-10-1980	20-11-1980
Salts		
CdSO ₄	125.25	99.25
Cd(NO ₃) ₂	126.90	152.20
F test	-	-
Concentration (ppm)		
0	116.50	110.00
100	80.50	145.25
500	170.00	138.50
1000	86.00	62.75
2000	177.50	172.25
F test	-	-
Plant		
A	171.70	206.20
B	80.50	45.25
F test	-	*

and Cladosporium herbarum were the main representatives of Dematiaceae. Other fungi namely Curvularia geniculata, Alternaria fasciculata, Botryotrichum pulluliform, stachybotrys atra, Alternaria geophila, Stemphylium verruculosum and Helminthosporium nodulosum were of comparatively sporadic frequency of occurrence on the isolation plates.

5. Mycelia sterilia represented only 2.1-6.1% of the total isolations, with an average of $4.0\% \pm 1.99$.

6. Ascomycetes fungi had almost the same frequency of occurrence like Mycelia sterilia representing 2.1-8.6% of the total isolations with an average of $5.2\% \pm 3.25$. Myrothecium verrucaria was the main species of most frequent occurrence, followed by very seldom occurring two genera Phoma humicola and Chaetomium magnum.

7. The genus Fusarium followed the Ascomycetes fungi in abundance. Only two species were detected on the isolation plates. These represented 0.5-7.0% of the isolated fungi with an average of $3.1\% \pm 3.31$. Fusarium oxysporum was the main species isolated from the different treatments, whereas F. roseum was of statistically lower frequency of occurrence.

Table 8 : Average numbers of the group Mycelia sterilia as affected by the two cadmium salts, different concentrations and the two plants Glycine max (A) and Zea mays (B).

Source of variance	Date of isolations	
	Average number	
	22-9-1980	20-11-1980
Salts		
CdSO ₄	71.20	76.25
Cd(NO ₃) ₂	64.90	114.20
F test	-	*
Concentration(ppm)		
0	132.50	140.00
100	74.00	72.50
500	61.25	122.50
1000	28.75	52.75
2000	43.75	88.50
F test	-	-
Plant		
A	98.40	154.00
B	37.70	36.50
F test	-	**

8. The last and least group of fungi was the genus Penicillium which represented 1.3-4.0% of the isolated fungi with an average of $2.7\% \pm 1.41$. Only 4 species were detected on the isolation plates. Penicillium janthinillum and P. coryophillum were more common compared with P. rubrum and P. puberulum.

b) Effect of cadmium salts :

The results presented in table 1-8 and a-e of the appendix and Fig. 1 revealed the following facts :

1. Soil treatment with different doses of cadmium sulphate or cadmium nitrate reduced the number of isolated Aspergillus species except for A. niger and A. terreus, Moniliaceae and Mycelia sterilia, from the rhizospheres of soy bean and corn compared with the controls. However, fluctuations in number of isolates of Myrothecium verrucaria, Phoma humicola, Chaetomium magnum, Fusarium oxysporum and F. roseum from cadmium-treated plots did not show any significant difference in the frequency of their occurrence. The remaining groups (Phycomycetes, Dematiaceae, Penicillium spp., Aspergillus niger and A. terreus) revealed higher number of isolates from the rhizospheres of soy bean or corn plants raised in cadmium-treated soils.

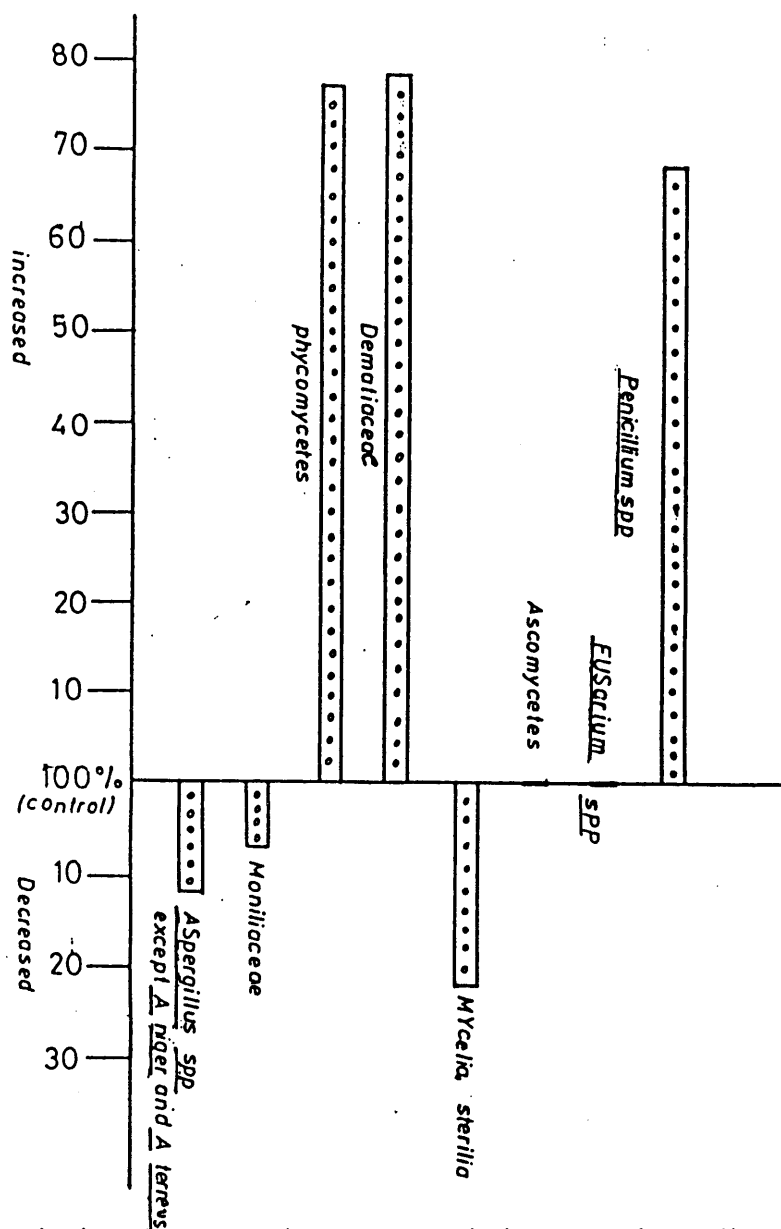


Fig (1) Percentage increase and decrease from the control (100%) of the different fungal groups, isolated under the different experimental treatments, from the rhizospheres of soybean and corn.

2. Aspergillus flavus, Cephalosporium curtisii, Stachybotrys atra, Penicillium janthinellum, Aspergillus clavatus, A. candidus and Mycelia sterilia were the main fungi which were highly sensitive to soil treatment with different doses of cadmium salts.

These observations might be attributed to one or more of the following facts:

i) The cultivation of soy bean or corn plants variably influenced growth of microorganism dependent on the composition of their root exudates.

ii) The lower counts of some organisms might be attributed to sensitivity of such fungi to the toxic effects of the cadmium ions supplemented to the soil.

iii) Selective action may explain the insensitivity or tolerance of other fungi to the presence of cadmium; a phenomenon that has been already reported by many investigators, for soil microorganisms.

iv) Root exudates may disturb the balance between the rhizosphere fungi, dependent on variation of seasonal conditions. Accordingly, growth of some fungi may be suppressed whereas other organisms may flourish.

B. EFFECT OF CADMIUM SALTS ON SOME GROWTH
CRITERIA OF REPRESENTATIVE FUNGI FROM
THE RHIZOSPHERE OF GLYCLINE MAX AND
ZEa MAYs

The results of the previous experiment clearly establish that the genus Aspergillus represent the largest number of rhizospheric fungi around Glycine max or Zea mays, A. niger was the most dominant and most tolerant to the various doses of either cadmium salts. Since this organism is rather difficult to manipulate under liquid culture conditions, we have chosen A. terreus for growth experiments though it comes second, in resistance to cadmium toxicity after Rhizopus oryzae (70 and 80% tolerance respectively).

Paecilomyces divaricata and Curvularia tetramera showed moderate tolerance (44-45% frequency) whereas Fusarium oxysporum was more sensitive (32% prevalence) to the toxic effects of cadmium. On the other hand, Cladosporium herbarum was highly sensitive to cadmium exhibiting only 12% frequency.

These 6 fungi, with various resistance to cadmium poisoning were selected for further laboratory investigations in order to study the physiological effects of direct cadmium contact with these fungi. Under all conditions, at least, 4 replicate samples were used for each treatment.

Spore Germination :

The results of spore germination were recorded with-
in a wide range of germination period in order to reach
around 50% spore germination of control samples whereby a
true picture of the effect of cadmium salts could be more
clear. Accordingly, it seems that spores of Curvularia,
Fusarium and Rhizopus were very active (germinating within
1.25-5.50 hours); Cladosporium and Aspergillus spores were
moderately active (germinating within 12-18 hours) while those
of Paecilomyces were very slow (germinating after 30 hours).

Table 9 and Fig. 2 show that germination of Rhizopus
oryzae spores (most tolerant) seemed almost unaffected by
either cadmium salts till 100 ppm whereas 1000 ppm totally arr-
ested germination. Fusarium spores (sensitive) and Curvularia
spores (moderately tolerant) behaved similarly though 1000
ppm cadmium nitrate reduced spore germination, for these two
organisms to almost 50% of the controls. Both cadmium salts
suppressed germination of Cladosporium spores with complete
inhibition at 1000 ppm; cadmium nitrate being less effective
particularly at 50 ppm.

50 ppm cadmium sulphate stimulated spore germination
of Aspergillus and Paecilomyces; a phenomenon that was

[Faint handwritten notes, possibly bleed-through from the reverse side.]

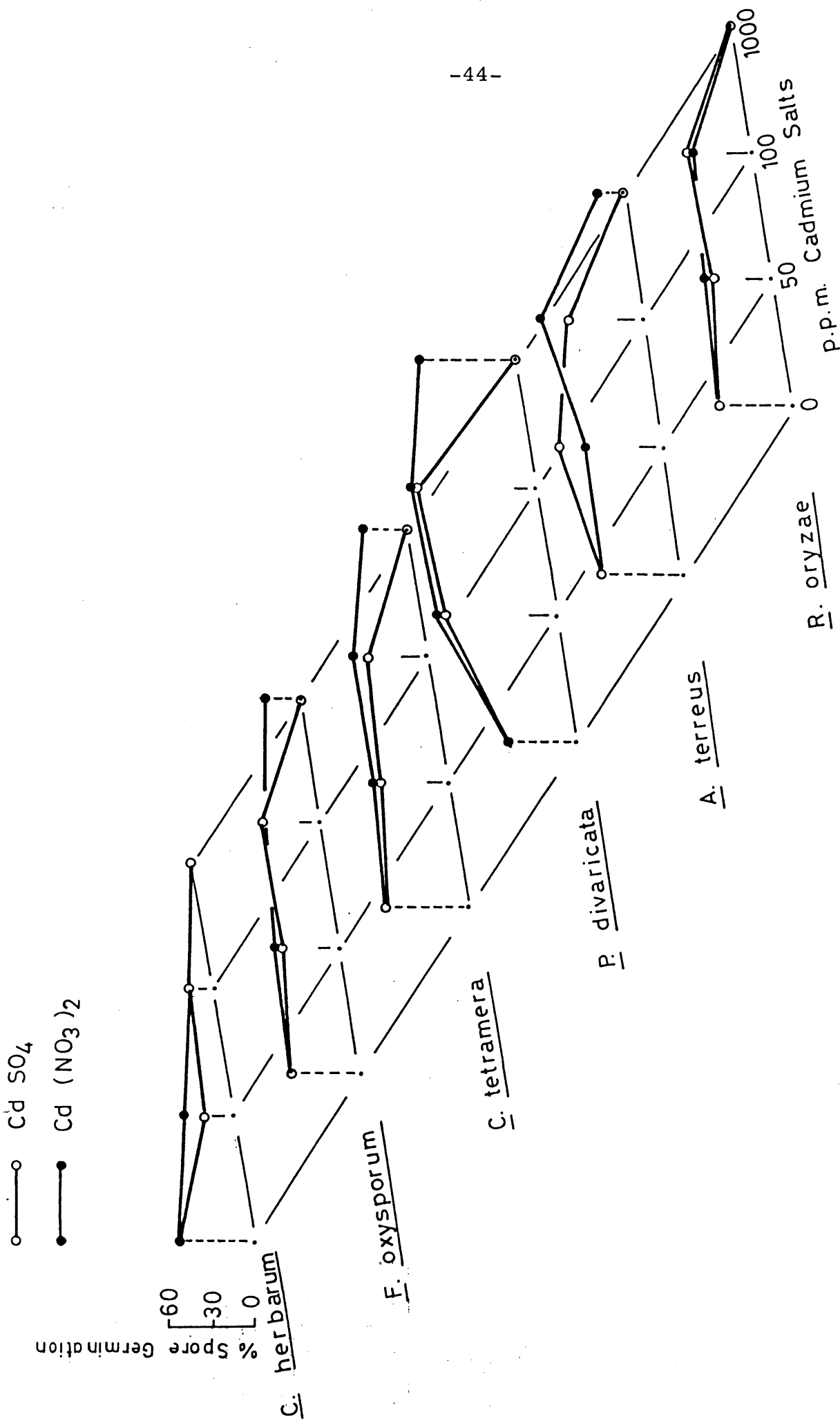


Fig.(2) Percentage spore germination of the different fungal species , on various concentrations of cadmium sulphate or cadmium nitrate.

alleviated (Aspergillus) or continued (Paecilomyces), at 100 ppm dose. Further increase in cadmium sulphate concentration stopped germination for both organisms. On the other hand, cadmium nitrate continuously enhanced spore germination of Paecilomyces till 1000 ppm dose whereas spore germination of Aspergillus was hardly affected at 50 ppm but was stimulated at 100 ppm and remarkably declined at 1000 ppm dose.

Mycelial Dry Weight :

Preliminary investigations, using Dox liquid medium, showed that Rhizopus oryzae, Cladosporium herbarum and Paecilomyces divaricata feebly produced fungal felts even after 10 days incubation at 28°C. These three fungi were unable to grow in cadmium-containing media whereas the remaining organisms exhibited a very weak or even no growth at 1000 ppm cadmium dose. Accordingly it was thought advisable to lower the cadmium concentration to 500 ppm and use potato dextrose medium for the growth of the above mentioned organisms. Unfortunately cadmium arrested the growth of Cladosporium and Paecilomyces even at 50 ppm dose. The incubation period for the remaining four fungi lasted for 7 days.

Table 10 and Fig. 3 show that dry weight gain by Rhizopus oryzae was hardly affected by either cadmium salts till 100 ppm above which a noticeable drop was observed, more

Table 10 : Dry weight gain, after seven days growth, by selected soil fungi on either Dox or potato dextrose media supplemented with various concentrations of cadmium sulphate or cadmium nitrate. (Mg per biomass).

Fungal species	Control	ppm cadmium sulphate				ppm cadmium nitrate			
		50	100	500	50	100	500	100	500
<u>Rhizopus oryzae</u>	244 + 8.3	236 + 8.0	224 + 7.6	107 + 3.6	218 + 7.4	210 + 7.1	146 + 4.9		
<u>Aspergillus terreus</u>	505 + 18.2	149 + 5.1	116 + 3.9	—	263 + 8.9	167 + 5.6	107 + 3.6		
<u>Curvularia tetramera</u>	496 + 17.9	282 + 9.4	181 + 6.1	132 + 4.5	349 + 12.6	246 + 8.3	158 + 5.3		
<u>Fusarium oxysporum</u>	308 + 11.1	330 + 11.9	145 + 4.8	99 + 3.3	235 + 7.9	142 + 3.9	124 + 4.2		

Table 11 : Dry weight gain, after seven days growth, by selected soil fungi on either Dox or potato dextrose media supplemented with various concentrations of cadmium sulphate or cadmium nitrate. (% of respective controls).

Fungal species	Control	ppm cadmium sulphate				ppm cadmium nitrate			
		50	100	500	50	100	500	100	500
<u>Rhizopus oryzae</u>	97	92	44	90	86	60			
<u>Aspergillus terreus</u>	30	23	—	52	33	20			
<u>Curvularia tetramera</u>	57	30	27	70	50	32			
<u>Fusarium oxysporum</u>	107	44	32	76	43	40			

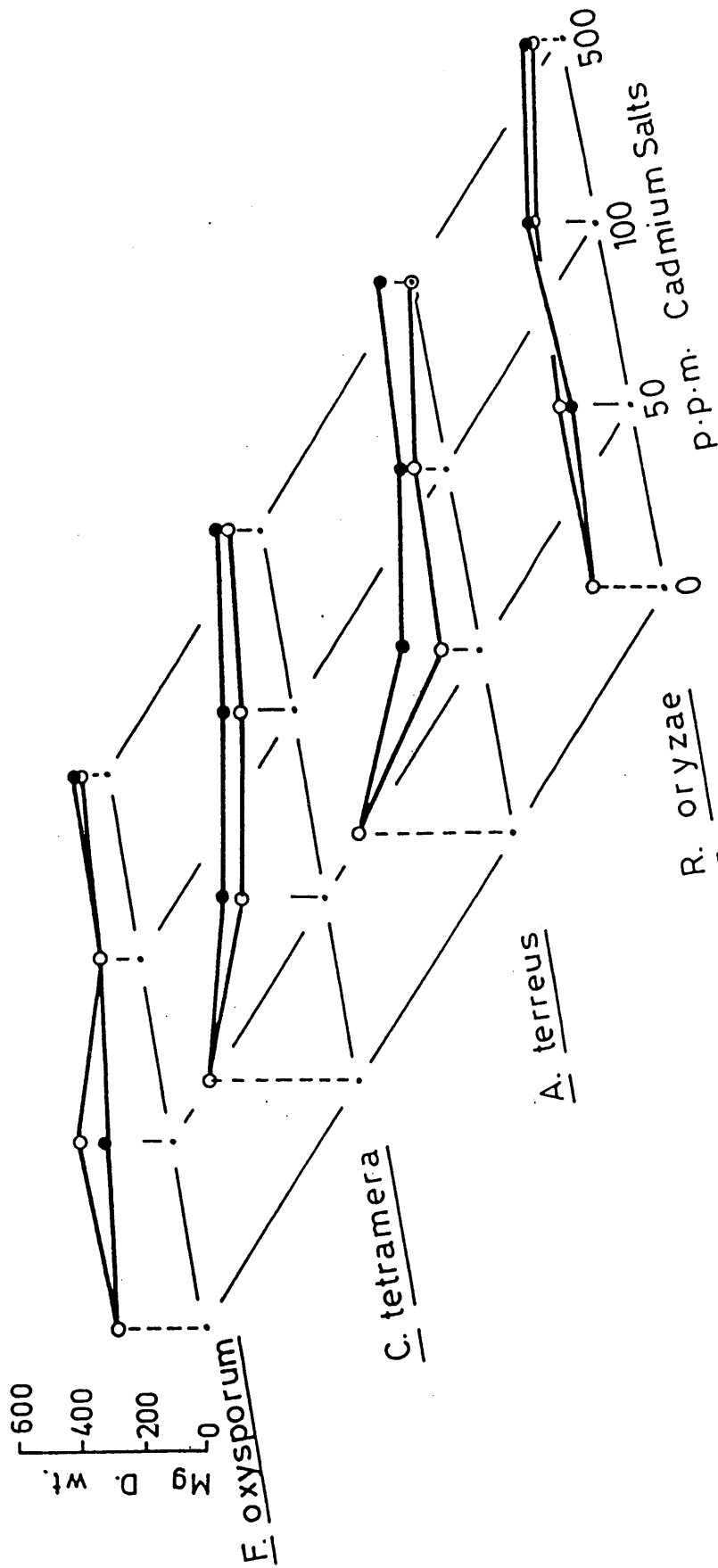


Fig.(3) Dry weight gain , after 7 days growth , of selected soil fungi , on either Dox or potato dextrose (*Rhizopus*) media , supplemented with various concentrations of cadmium sulphate or cadmium nitrate (Mg per 1 g D. wt. of Biomass).

prominantly in presence of cadmium sulphate. Dry weight gain by Aspergillus terreus was drastically inhibited by the cadmium ions; still sulphate being more effective than nitrate especially at the larger doses. Curvularia and Fusarium behaved similarly though the loss of weight was much less than in Aspergillus. Table 11 clearly represents these observations.

Nitrogen Secretion :

Table 12 and Fig. 4 show that 50 and 100 ppm cadmium salts slightly, if at all, affected the total nitrogen secretion by Rhizopus oryzae whereas 500 ppm slightly enhanced such process. Similarly both cadmium salts had the same stimulatory effect on nitrogen secretion by Curvularia tetramera, that was slightly furthered with increasing the cadmium doses. The same applies to Fusarium oxysporum though cadmium sulphate was more effective than cadmium nitrate.

In presence of cadmium sulphate, Aspergillus terreus secreted the largest amount of nitrogen till 100 ppm dose whereas 500 ppm did not allow growth of the fungus. Cadmium nitrate seemed less effective causing slight increase of nitrogen secretion when supplied at 100 ppm level that was remarkably furthered at 500 ppm concentration recording the

Table 12: Nitrogen secretion after seven days growth, by selected soil fungi, on either Dox or potato dextrose (Rhizopus) Media, supplemented with various concentrations of cadmium sulphate or cadmium nitrate. (mg per 1 g D. wt. of biomass).

Fungal species	Control	ppm cadmium sulphate			ppm cadmium nitrate		
		50	100	500	50	100	500
Amino	<u>R. oryzae</u>	1.64+0.09	1.71+0.09	2.11+0.10	1.26+0.08	2.76+0.12	3.67+0.15
	<u>A. terreus</u>	0.18+0.01	1.38+0.08	—	0.47+0.06	0.47+0.05	0.38+0.05
	<u>C. tetramera</u>	0.34+0.05	0.44+0.05	0.99+0.07	0.43+0.05	0.48+0.06	0.43+0.05
	<u>F. oxysporum</u>	0.38+0.05	0.86+0.07	1.91+0.10	0.46+0.06	0.48+0.05	1.10+0.08
Peptide	<u>R. oryzae</u>	10.53+0.39	7.71+0.29	17.57+0.63	7.72+0.29	9.62+0.35	13.15+0.47
	<u>A. terreus</u>	8.02+0.30	15.64+0.56	—	8.44+0.32	14.25+0.51	26.78+0.92
	<u>C. tetramera</u>	9.11+0.34	13.12+0.47	21.59+0.68	14.56+0.52	15.12+0.53	19.82+0.70
	<u>F. oxysporum</u>	6.66+0.26	7.00+0.27	27.78+0.88	4.26+0.18	14.01+0.49	22.39+0.75
other soluble	<u>R. oryzae</u>	6.06+0.24	4.62+0.19	6.02+0.23	9.32+0.36	6.48+0.25	12.63+0.46
	<u>A. terreus</u>	5.49+0.23	8.58+0.32	—	2.74+0.13	5.32+0.21	15.99+0.57
	<u>C. tetramera</u>	6.75+0.26	7.15+0.28	8.29+0.33	7.44+0.28	9.01+0.31	8.89+0.34
	<u>F. oxysporum</u>	3.53+0.16	4.44+0.19	8.88+0.34	3.53+0.16	5.23+0.22	8.03+0.30
Total	<u>R. oryzae</u>	18.23+0.64	14.04+0.50	25.70+0.90	18.90+0.67	18.86+0.66	29.45+1.02
	<u>A. terreus</u>	13.70+0.49	24.60+0.85	—	11.65+0.43	19.74+0.68	43.25+1.44
	<u>C. tetramera</u>	16.20+0.59	20.71+0.72	30.87+1.06	22.43+0.78	24.61+0.86	29.14+1.00
	<u>F. oxysporum</u>	10.57+0.38	12.30+0.45	38.57+1.32	8.24+0.31	19.72+0.69	31.52+1.09

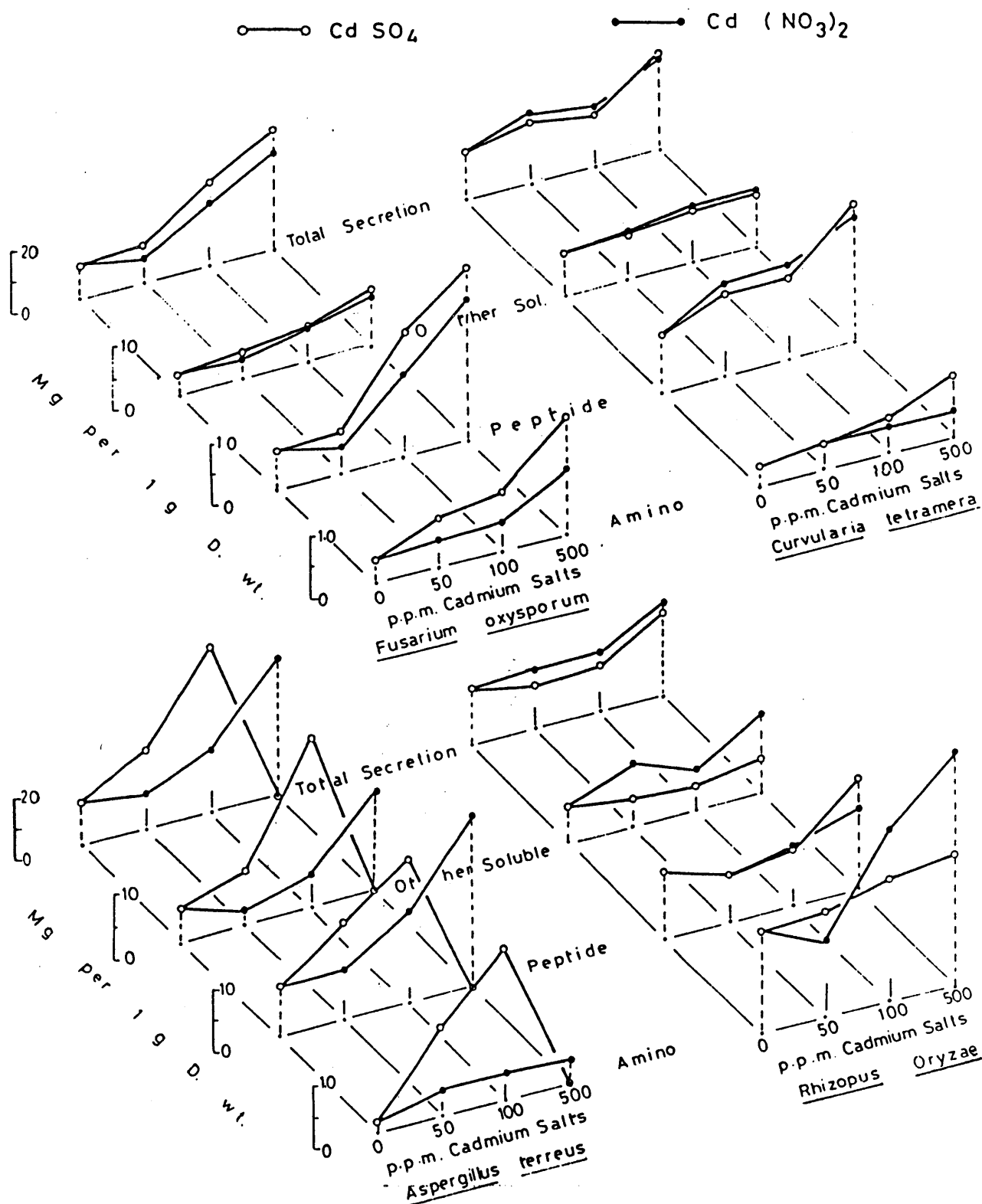


Fig.(4) Nitrogen secretion, after 7 days growth, of selected soil fungi, on either Dox or potato dextrose (*Rhizopus*) media, supplemented with various concentrations of cadmium sulphate or cadmium nitrate (Mg per 1 g D. wt. of Biomass).

the largest secretion in cadmium nitrate media. Under all conditions peptide and/or other soluble nitrogen majorly participated in these respects whereas fluctuations in amino nitrogen were only apparent in Aspergillus media particularly when supplemented with cadmium nitrate.

Nitrogen Components of Biomass :

Table 13 and Fig. 5 clearly show that the smallest cadmium dose (50 ppm) hardly affected the total nitrogen content of Rhizopus oryzae; a phenomenon that continued with further rise of cadmium nitrate concentration but larger doses of cadmium sulphate suppressed nitrogen accumulation more prominently at 500 ppm level.

On the other hand, though cadmium sulphate seemed of little effect on nitrogen content of Aspergillus terreus yet 500 ppm dose completely arrested growth of the fungus. In the meantime, cadmium nitrate had a stimulatory effect that was most apparent at 100 ppm concentration but slightly attenuated with further increase of concentration of the salt.

On the contrary, both salts suppressed nitrogen accumulation by Curvularia tetramera ; a phenomenon that was highly apparent at the larger than smaller doses of the salts.

Fungal species	Ammonia	Amino	Peptide	Other soluble	Total soluble	Protein	Nucleopro- tein.	Other Insoluble	Total Insoluble	Total Nitrogen
Treatment										
<i>R. oryzae</i>	0.14±0.02	2.33±0.11	6.76±0.27	8.67±0.33	17.90±0.63	5.62±0.22	2.78±0.14	8.40±0.31	16.80±0.60	34.70±1.18
<i>A. terreus</i>	0.51±0.04	3.96±0.17	4.44±0.17	2.39±0.12	11.30±0.41	3.03±0.14	3.43±0.16	3.86±0.14	10.32±0.38	21.62±0.76
<i>C. tetramera</i>	0.21±0.02	4.44±0.18	1.78±0.11	4.57±0.18	11.00±0.40	4.21±0.16	2.30±0.12	3.37±0.13	9.88±0.37	20.88±0.73
<i>F. oxysporum</i>	0.15±0.02	5.05±0.20	8.05±0.30	3.83±0.16	17.08±0.60	4.28±0.17	2.53±0.13	1.11±0.07	7.92±0.32	25.00±0.87
<i>Cd504</i>	0.37±0.04	1.81±0.10	6.51±0.26	6.33±0.25	15.02±0.54	5.96±0.23	1.41±0.09	8.41±0.30	15.78±0.57	30.80±1.06
<i>R. oryzae</i>	0.25±0.02	2.88±0.13	6.59±0.25	9.99±0.36	19.71±0.70	5.30±0.22	1.44±0.08	7.97±0.30	14.71±0.52	34.42±1.19
<i>Cd(N03)2</i>	0.38±0.03	4.57±0.19	3.68±0.14	2.80±0.12	11.43±0.41	2.40±0.11	3.71±0.16	4.01±0.17	10.12±0.37	21.55±0.75
<i>A. terreus</i>	0.44±0.04	3.65±0.16	4.74±0.18	3.05±0.13	11.88±0.43	2.89±0.12	3.50±0.15	6.94±0.26	13.38±0.48	25.26±0.86
<i>Cd(N03)2</i>	0.26±0.02	4.28±0.17	2.59±0.12	3.28±0.15	10.41±0.39	3.41±0.15	2.21±0.11	2.55±0.12	8.17±0.31	18.58±0.66
<i>C. tetramera</i>	0.35±0.02	2.82±0.12	4.04±0.15	1.62±0.09	8.83±0.34	3.68±0.15	1.60±0.10	1.14±0.06	6.42±0.27	15.25±0.56
<i>Cd(N03)2</i>	0.46±0.04	10.05±0.33	5.73±0.24	4.78±0.19	21.02±0.74	4.71±0.17	2.04±0.11	2.54±0.11	9.29±0.34	30.39±1.07
<i>Cd504</i>	0.61±0.05	7.44±0.28	5.69±0.23	6.84±0.26	20.58±0.72	5.68±0.21	1.24±0.09	2.99±0.13	9.91±0.36	30.49±1.06
<i>F. oxysporum</i>	0.34±0.03	1.69±0.09	6.05±0.22	5.64±0.23	13.74±0.49	4.86±0.18	1.33±0.09	7.54±0.29	13.73±0.60	27.45±0.95
<i>R. oryzae</i>	0.29±0.03	1.04±0.07	6.67±0.24	7.19±0.27	15.19±0.54	6.36±0.24	1.84±0.10	10.35±0.38	18.55±0.65	33.74±1.16
<i>Cd(N03)2</i>	0.66±0.05	5.59±0.23	4.16±0.17	3.64±0.16	14.05±0.51	2.44±0.12	3.48±0.15	4.61±0.17	9.93±0.37	23.98±0.83
<i>A. terreus</i>	0.74±0.06	6.15±0.24	5.64±0.22	4.51±0.19	17.04±0.51	2.91±0.13	2.63±0.13	5.92±0.22	11.46±0.41	28.50±1.00
<i>Cd(N03)2</i>	0.31±0.03	3.93±0.16	2.81±0.12	2.88±0.13	9.93±0.36	2.94±0.13	2.38±0.12	2.90±0.13	8.22±0.32	18.15±0.63
<i>C. tetramera</i>	0.30±0.02	2.89±0.11	4.02±0.14	1.54±0.09	8.75±0.34	3.52±0.16	2.97±0.14	4.20±0.18	10.68±0.40	19.44±0.68
<i>Cd(N03)2</i>	0.41±0.04	4.03±0.16	4.11±0.16	5.21±0.22	13.76±0.50	4.42±0.17	1.62±0.10	1.57±0.10	7.61±0.29	21.37±0.74
<i>Cd504</i>	0.25±0.02	7.57±0.29	5.63±0.22	6.15±0.24	19.60±0.69	6.78±0.25	1.56±0.09	3.09±0.13	11.43±0.41	31.03±1.06
<i>F. oxysporum</i>	0.31±0.03	1.72±0.09	5.79±0.21	4.12±0.17	11.94±0.44	4.74±0.19	1.26±0.09	8.02±0.30	14.02±0.50	25.96±0.88
<i>Cd(N03)2</i>	0.32±0.03	1.01±0.06	6.73±0.22	6.43±0.25	14.49±0.49	7.06±0.26	1.31±0.09	9.21±0.35	17.58±0.63	32.07±1.10
<i>R. oryzae</i>	0.73±0.06	6.72±0.26	4.66±0.18	4.22±0.18	16.33±0.58	2.54±0.12	1.60±0.10	2.25±0.12	6.39±0.25	25.72±0.86
<i>Cd(N03)2</i>	0.32±0.03	2.09±0.11	2.64±0.11	1.42±0.08	6.47±0.25	2.78±0.13	2.26±0.12	1.80±0.09	6.84±0.28	13.31±0.48
<i>C. tetramera</i>	0.23±0.02	2.66±0.12	4.55±0.18	1.26±0.08	8.70±0.32	3.77±0.16	1.28±0.11	1.79±0.09	6.84±0.27	15.54±0.55
<i>Cd(N03)2</i>	0.23±0.02	5.23±0.22	3.57±0.15	5.94±0.24	14.97±0.53	4.75±0.17	1.73±0.10	1.01±0.06	7.49±0.28	22.46±0.78
<i>F. oxysporum</i>	0.22±0.02	8.44±0.32	5.18±0.20	8.33±0.31	22.17±0.78	5.54±0.22	1.61±0.09	1.99±0.09	9.14±0.35	31.31±1.07
<i>Cd(N03)2</i>										

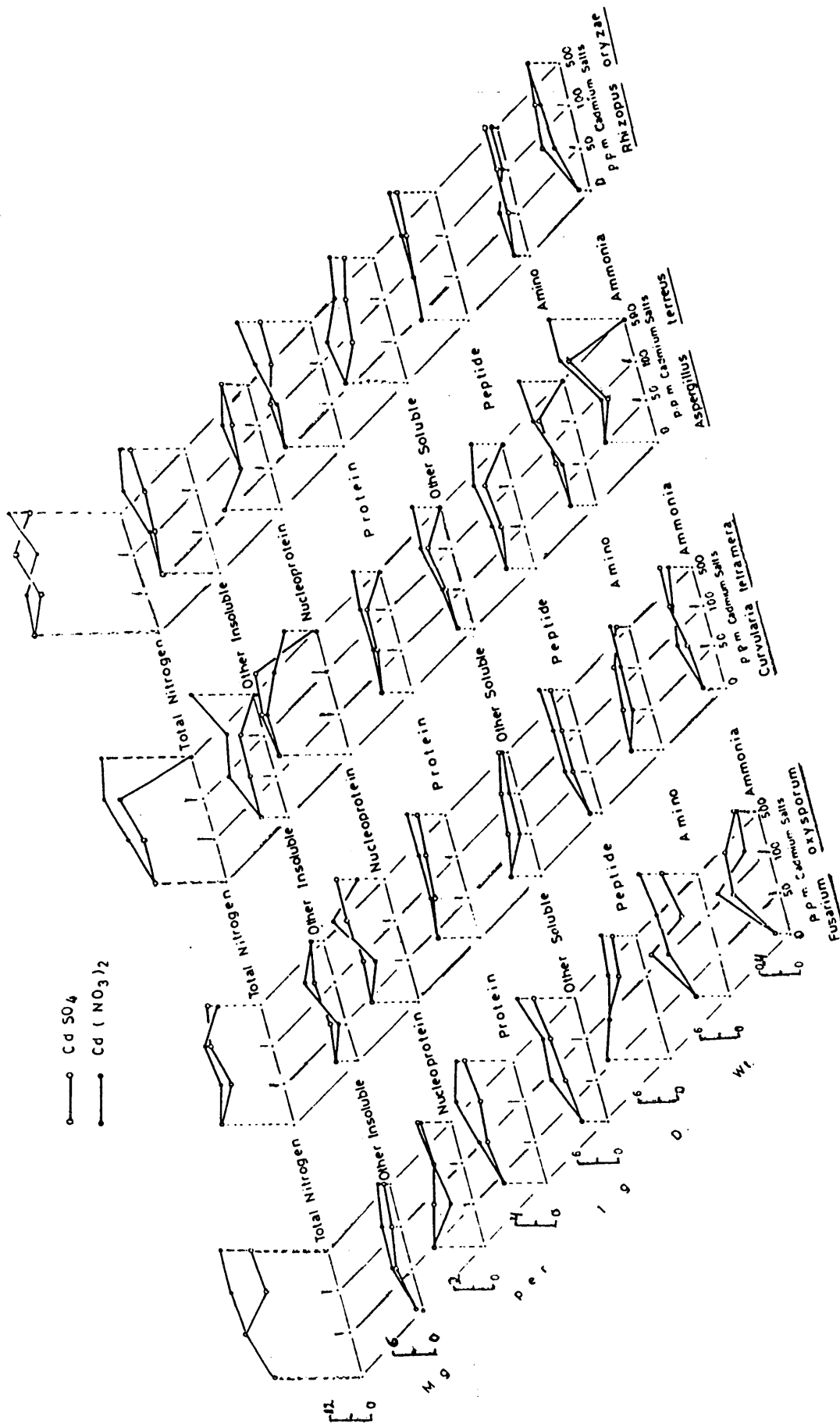


Fig. (5) Nitrogen components after 7 days growth of selected soil fungi on either Dox or potato dextrose (Rhizopus) media, supplemented with various concentrations of cadmium sulphate or cadmium nitrate (Mg per 1 g. D. wt. of Biomass)

Meanwhile the stimulatory effects of both salts on nitrogen gain by Fusarium oxysporum continued in presence of the larger doses of cadmium nitrate but the increased concentrations of cadmium sulphate were slightly inhibitory.

Apart from these fluctuations, cadmium slightly increased the ammonia content of the biomass with the concomitant drop in amino and other soluble and/or nucleoprotein nitrogen, whereas protein and other insoluble nitrogen were almost unaffected except with larger doses of cadmium nitrate that favoured larger increased in amino nitrogen of the four fungi lest Rhizopus accompanied by comparatively lower other insoluble nitrogen.

Phosphorus Components of Biomass :

Table 14 and Fig. 6 show that cadmium salts slightly, if at all, affected the total phosphorus content of Fusarium oxysporum mycelia, regardless of concentration, Rhizopus oryzae felts, similarly responded though cadmium sulphate, at its higher concentrations slightly increased the total phosphorus content. On the other hand, the cadmium salts stimulated phosphorus accumulation by Curvularia tetramera felts; more prominently at the larger doses. Similar effects were observed with cadmium nitrate-supplied Aspergillus terreus mycelia but cadmium sulphate was less effective or even stopped

Table 14 : Phosphorus components after 7 days growth, of selected soil fungi, on either Dox or potats dextrose media, supplemented with various concentrations of cadmium sulphate or cadmium nitrate (Mg per 1 g D. wt of Biomass).

Fungal species	P component	Control	ppm cadmium sulphate				ppm cadmium nitrate			
			50	100	500	50	100	50	100	50
Inorganic P	R.oryzae	3.98+0.17	3.88+0.17	3.42+0.14	2.61+0.11	4.83+0.19	4.66+0.18	4.73+0.19		
	A.terreus	3.48+0.16	3.16+0.15	5.08+0.20	—	4.00+0.16	4.51+0.19	4.53+0.18		
	C.tetramera	3.31+0.15	3.81+0.16	3.01+0.13	1.14+0.06	3.36+0.14	2.89+0.12	2.41+0.11		
	F.oxysporum	6.46+0.25	5.73+0.23	3.97+0.16	2.87+0.11	4.97+0.21	6.57+0.25	4.29+0.17		
Soluble P	R.oryzae	1.59+0.08	3.91+0.17	8.06+0.30	9.11+0.32	1.06+0.07	1.29+0.08	1.04+0.07		
	A.terreus	4.44+0.15	10.22+0.38	6.35+0.24	—	10.46+0.37	4.88+0.19	4.05+0.16		
	C.tetramera	3.10+0.13	3.42+0.15	6.77+0.25	7.31+0.27	6.19+0.24	5.33+0.21	4.51+0.17		
	F.oxysporum	15.44+0.55	13.26+0.48	19.47+0.63	12.85+0.46	14.56+0.52	16.36+0.58	14.57+0.50		
Total P	R.oryzae	5.57+0.23	7.79+0.28	11.48+0.41	11.72+0.41	5.89+0.24	5.95+0.24	5.77+0.22		
	A.terreus	7.92+0.30	13.38+0.46	11.43+0.40	—	14.46+0.50	9.39+0.35	8.58+0.32		
	C.tetramera	6.41+0.24	7.23+0.28	9.78+0.35	8.45+0.30	9.55+0.35	8.22+0.32	6.92+0.26		
	F.oxysporum	21.90+0.77	18.99+0.67	23.44+0.87	15.73+0.55	19.53+0.68	22.93+0.80	18.86+0.63		
Insoluble P	R.oryzae	8.95+0.34	7.04+0.26	8.88+0.33	8.84+0.32	9.90+0.35	8.11+0.29	9.37+0.33		
	A.terreus	3.30+0.14	3.86+0.16	2.68+0.12	—	6.09+0.23	4.93+0.20	7.45+0.27		
	C.tetramera	1.42+0.08	2.33+0.11	3.49+0.14	6.51+0.26	2.65+0.12	2.51+0.11	6.30+0.24		
	F.oxysporum	6.27+0.25	4.41+0.17	2.24+0.10	6.16+0.25	1.70+0.09	1.46+0.08	6.33+0.25		
Total P	R.oryzae	14.52+0.51	14.83+0.52	20.36+0.70	20.56+0.71	25.79+0.86	14.06+0.48	15.14+0.54		
	A.terreus	11.22+0.41	17.24+0.61	14.11+0.48	—	20.55+0.72	14.32+0.50	16.03+0.55		
	C.tetramera	7.83+0.30	9.56+0.37	13.27+0.46	14.96+0.55	12.20+0.45	10.73+0.40	13.92+0.50		
	F.oxysporum	28.17+0.96	23.40+0.81	15.68+0.56	21.89+0.75	21.23+0.75	24.39+0.85	25.19+0.85		

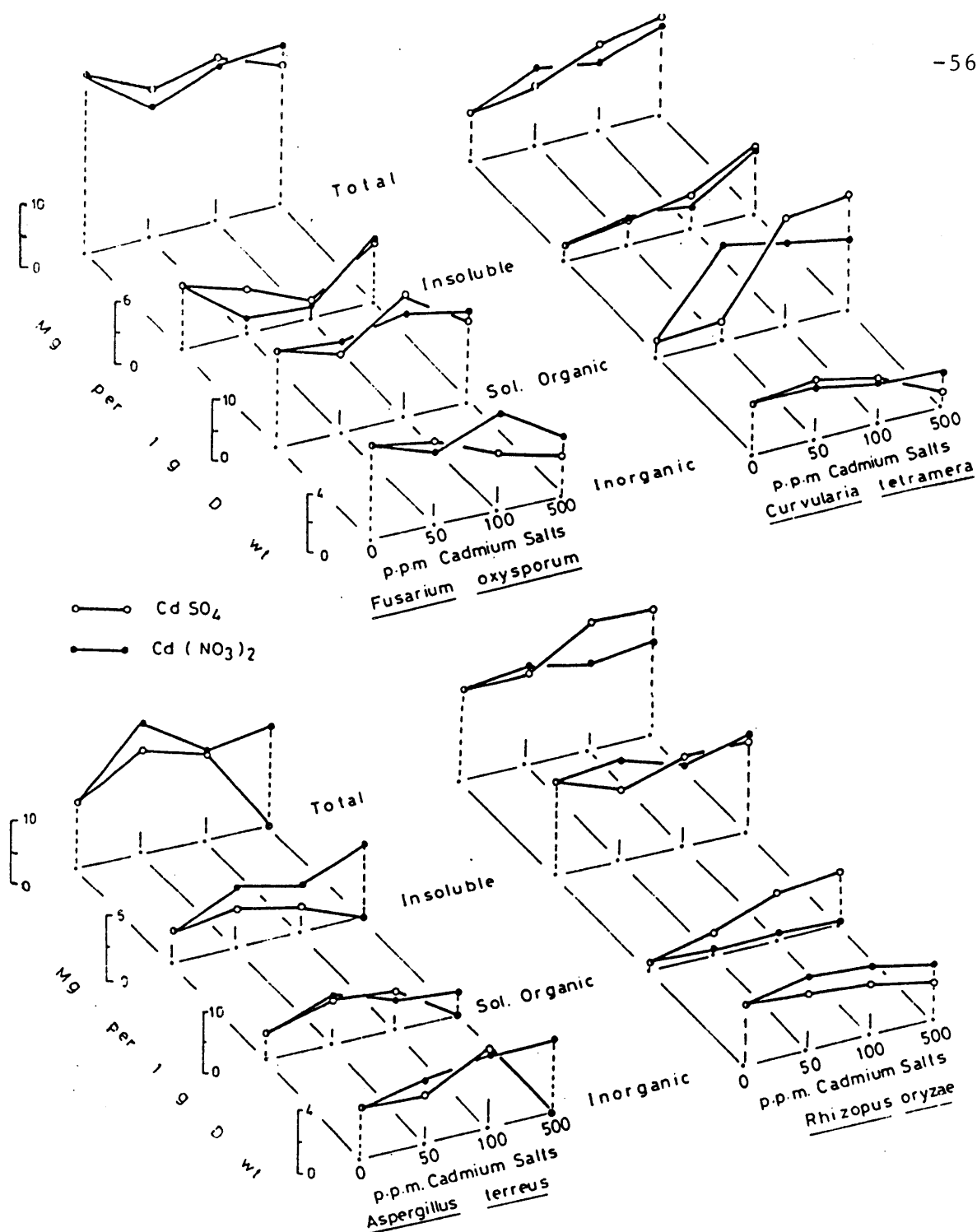


Fig. (6) Phosphorus components after 7 days growth , of selected soil fungi , on either Dox or potato dextrose (*Rhizopus*) media , supplemented with various concentrations of cadmium sulphate or cadmium nitrate (Mg per 1 g D.wt. of Biomass).

growth at 500 ppm dose.

Inspite of these fluctuations, cadmium sulphate favoured larger accumulation of soluble organic phosphorus particularly at 100 ppm level compared with cadmium nitrate which exerted no effect. Still both salts hardly affected insoluble phosphorus content of Rhizopus but increased that of either Curvularia or Aspergillus, particularly at the larger doses, whereas the severe drop in this component by the lower doses was alleviated by rise of concentration in Fusarium media.

Total Polysaccharide Content :

Table 15 and Fig. 7 show that cadmium salts largely increased total polysaccharide content of both Rhizopus oryzae and Fusarium oxysporum felts ; nitrate salt being more effective than sulphate salt though larger doses were less stimulatory for Fusarium. Conversely both salts inhibited total polysaccharide accumulation in Curvularia tetramera mycelium; more prominently with cadmium sulphate administration. Both salts seemed without effect on Aspergillus terreus polysaccharide content though the largest doses of cadmium nitrate suppressed polysaccharide accumulation, whereas that of cadmium sulphate totally stopped growth.

Organic Acid Secretion :

Table 16 and Fig. 8 show that cadmium salts equally stimulated organic acid secretion by Rhizopus felts ; a phenomenon that was furthered with rise of concentration whereby sulphate was more effective than nitrate. On the other hand, the stimulatory effects of cadmium sulphate on organic acid secretion by Aspergillus was far greater than those of cadmium nitrate though at 500 ppm, cadmium sulphate arrested growth.

In the meantime, both cadmium salts were most effective in inducing organic acids secretion when supplemented, to Curvularia or Fusarium, at 100 ppm concentration, above or below which both salts were less effective, if not suppressive. Under both conditions, nitrate was less stimulatory but more inhibitory particularly at its largest dose.

Table 15: Total polysaccharide content after 7 days growth of selected fungi, on either Dox or potato dextrose media, supplemented with various concentrations of cadmium sulphate or cadmium nitrate.
(Mg per 1g D. wt of Biomass).

Fungal species	Control	ppm cadmium sulphate			ppm cadmium nitrate		
		50	100	500	50	100	500
<u>Rhizopus oryzae</u>	251.1+8.48	350.8+11.86	384.6+12.91	353.2+11.29	422.0+14.33	358.3+12.13	381.7+12.90
<u>Aspergillus terreus</u>	346.6+11.74	338.1+11.45	356.4+12.06	-	337.1+11.42	326.8+11.38	277.5+9.36
<u>Curvularia tetramera</u>	410.9+13.93	302.7+10.29	350.9+11.83	239.8+8.12	331.3+11.22	380.0+12.84	327.3+11.10
<u>Fusarium oxysporum</u>	144.0+4.85	172.6+5.80	152.5+5.14	147.9+5.38	193.3+6.48	189.8+6.36	157.7+8.60

Table 16: Total organic acid secretion after 7 days growth of selected fungi on either Dox or potato-dextrose media, supplemented with various concentrations of cadmium sulphate or cadmium nitrate. (Mg per 1g D.wt of Biomass).

Fungal species	Control	ppm cadmium sulphate			ppm cadmium nitrate		
		50	100	500	50	100	500
<u>Rhizopus oryzae</u>	22.54+0.54	23.31+0.81	46.43+1.57	97.70+3.26	30.48+1.04	48.62+1.64	73.97+2.48
<u>Aspergillus terreus</u>	13.66+0.46	55.03+1.86	86.21+2.89	-	39.54+1.36	43.20+1.47	54.21+1.83
<u>Curvularia tetramera</u>	11.29+0.38	37.59+1.28	53.04+1.79	30.30+1.03	36.68+1.25	44.72+1.51	30.38+1.04
<u>Fusarium oxysporum</u>	45.78+1.55	26.67+0.92	78.62+2.64	51.52+1.78	34.89+1.20	54.93+1.86	26.61+0.92

0004

● — Cd (NO₃)₂

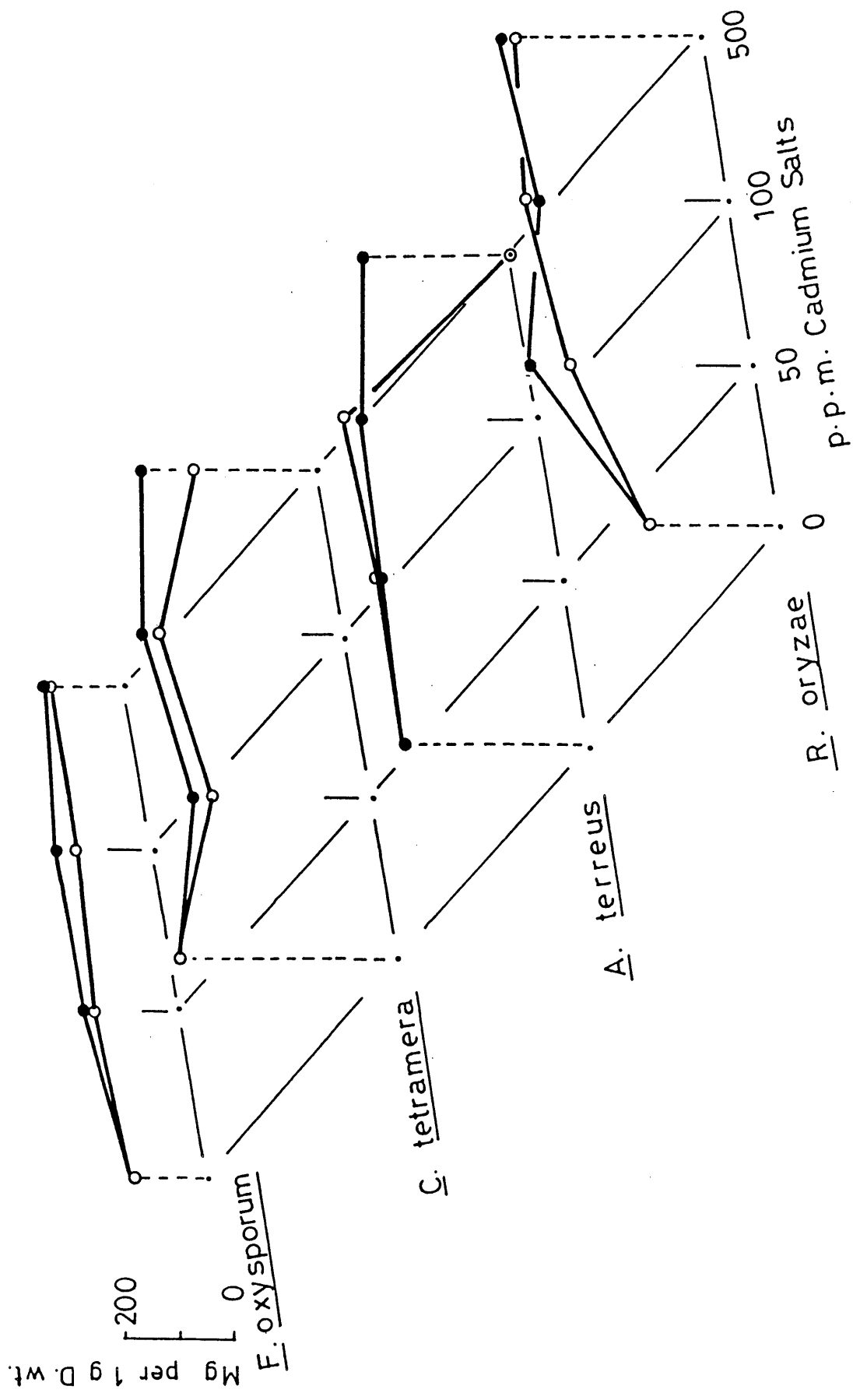


Fig. (7) Total polysaccharide content after 7 days growth, of selected soil fungi , on either Dox or potato dextrose (Rhizopus) media , supplemented with various concentrations of cadmium sulphate or cadmium nitrate (Mg per 1g D. wt. of Biomass)

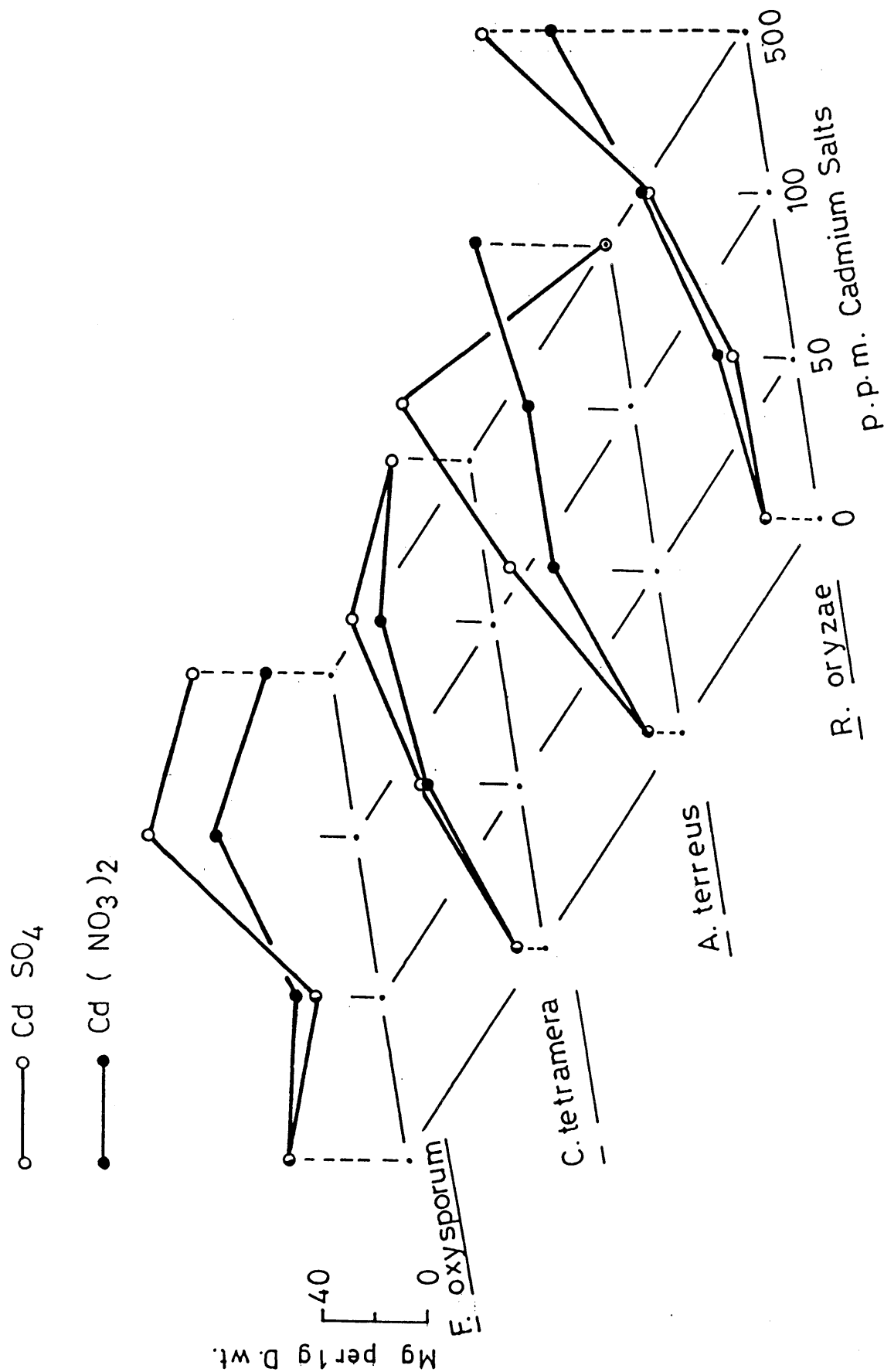


Fig. (8) Total organic acid secretion after 7 days growth , of selected soil fungi, on either Dox or potato dextrose (*Rhizopus*) media , supplemented with various concentrations of cadmium sulphate or cadmium nitrate (Mg per 1g D.wt. of Biomass).

PART III

- A) DISCUSSION
- B) SUMMARY
- C) REFERENCES
- D) APPENDIX

PART III

DISCUSSION

The plant, the soil, and the microflora form a biological system, the various parts of which are bound together by intricate interrelationship. Information in this system can be achieved by analysing the separate parts and their relationship and integrating the obtained results. Although some ways of influencing the compositions of the rhizosphere microflora are known, yet there is still much to be studied. On the basis of previous findings, it was argued that the rhizospheric microflora can exert their influence by acting on the plant metabolic processes, by modifying the environmental conditions or by consuming chemical or biological preparations.

On the other hand, all the phenomena operating in the struggle for existence manifest themselves in the extremely complex microbiological community of the soil. As a result of such struggle, certain groups and types of microorganisms eventually establish themselves as dominant forms in the community and others are relegated to the sub-dominant level. Thus an equilibrium is established which is characteristic of the soil, and which shifts and fluctuates as the environmental factors (temperature, moisture, treatment and cropping system) changes.

Cadmium is unique, among chemicals, in nature since it is always found in association with zinc. However zinc is an essential element to living organisms whereas cadmium has no known useful biological function. In fact cadmium is ranked among the most hazardous trace elements in the environment. The complexing of the metal ion with various organic molecules plays an important role in its toxicity to bacteria as well as to other organisms (Nriagu, 1980).

In the present investigation, the mycoflora in rhizospheres of soybean and corn plants, raised under four dosage range of cadmium sulphate or cadmium nitrate, were studied with the aim of elucidating the following points :

- a) The effect of raising soybean and corn plants on the soil mycoflora as represented by the rhizosphere population.
- b) The influence of cadmium sulphate or cadmium nitrate on the ability of soil fungi to survive in the rhizosphere of these two cultivated plants.

Such observations would naturally lead to a better understanding of the influence of cadmium on the natural balance between soil microorganisms; the upsetting of which may be in itself harmful to the plant.

The results of the present investigation revealed the following facts :

1) The highest total number of fungi, isolated from the rhizosphere of both soybean and corn plants was recorded for the cadmium-free soils. Such high values may be attributed to larger amounts of nutrients and/or chemical substances promoting growth of fungi, by soybean or corn plants roots, as already suggested by Rovira (1959) and Rouatt~~e~~et al., (1963). The lower counts recorded for cadmium-treated soils might be the result of the toxic or suppressive effects on the growth of the higher plants (c.f. Al-Wakil, 1981) which in turn will reflect itself on the amount and/or quality of root exudates. In the meantime, at the experimental concentrations, cadmium is toxic to the microorganisms. These deductions were further supported by similar observations by earlier workers (Hewitt, 1953 ; Page et al., 1972; Miller et al., 1973). Zibilske and Wagner (1982) recorded that soil treatment with cadmium did not affected the bacterial or fungal counts for two weeks after which both counts were reduced without affecting fungal intergenus relations.

Since cadmium salts were applied to natural garden soil (natural habitat for microorganisms where other elements viz. lead, copper, zinc or nickel are prevailing) then the

synergistic effects of such ions might also play a role in lowering the number of rhizospheric mycoflora.

In this connection it may be mentioned that Kneip (1978) found that a combination of cadmium and nickel did not clearly show additive toxicity to an ecosystem consisting of fish, plankton and benthic organisms. Addition of mercury, copper, zinc, cadmium and lead to lake water showed that the metals were more toxic in combination with one another than when they present alone in higher concentrations (Gachter, 1976). Moshe et al (1972) observed the synergistic effects on Chlorella sorokiniana when cadmium, copper, nickel and chromium were added together. In fact, zinc accentuated cadmium toxicity (Hutchinson and Czyrska, 1975) whereas low concentrations of lead (0.1 to 1 mg/l.) increased cadmium toxicity (Pietilainen, 1975). Synergism was observed in solutions where concentrations of cadmium were greater than concentrations of lead. Cadmium toxicity was found more pronounced when it was added to lake water than to laboratory medium. Analysis revealed that lake water contained lead, copper, zinc, nickel and cadmium. Therefore, its higher toxicity was probably caused by the synergistic effects of the metals (Burnison et al., 1975).

2) Aspergilli represented the group of highest frequency of occurrence, under the different experimental conditions. It represented almost half the total number of isolations of the rhizosphere fungi. This is in accordance with the previous findings by Waksman (1917), Jensen (1931), Sabet (1935), Tolba et al., (1966), Naim (1967b), Moubasher and Moustafa (1970) and Ali (1977).

Aspergillus niger revealed the highest frequency of occurrence. Numbers and percentages of isolation of this fungus showed a highly statistically significant difference from the corresponding values for other species isolated during this study. The remaining groups of fungi which appeared on the isolation plates are recorded, in the following descending order, according to their frequency of occurrence :
Moniliaceae (excluding Aspergillus and Penicillium), Phycomycetes, Dematiaceae, Mycelia sterilia, Ascomycetes, Fusarium spp. and Penicillium spp.

3) The fungi isolated and identified, during this study, were almost similar in type and degree of prevalence to those recorded from similar soils in other warm countries (Nour, 1956; Moubasher and El-Dohlob (1970); Tolba and Ali, 1972; Fathi et al., (1975); Ali, 1977).

4) The frequency of the isolated fungal groups behaved differently according to time of isolation, and hence according to the prevailing environmental conditions, plant type and age. The observed differences may be attributed to one or more of the following factors :

- a) Direct effect of temperature on the growth of fungi, the optimal temperature for one fungus may not be favourable for others (Cochrane, 1958 ; Rouatt, et al., 1963).
- b) The effect of temperature on quality and quantity of amino acids elaborated by plant roots and the effect of such amino acids on the microbial development within the root zone (Rovira, 1959).
- c) Effect of temperature on plant growth and hence on the nature and amount of root exudates which, in turn, affect the microbial population in the root zone (Rouatt et al., 1963).

5) Cadmium nitrate or cadmium sulphate lowered the number of certain rhizosphere fungi of corn and soybean whereas other members revealed higher or similar values to those of untreated soils. Aspergillus flavus, Cephalosporium curtisii, Stachybotrys atra, Penicillium janthinellum, Aspergillus

candidus, and *Mycelia sterilia* (hyaline) were greatly decreased by soil treatment with cadmium. Tatsuyama et al., (1975 c) reported that Penicillium lilacinum was strongly sensitive to copper, zinc and cadmium while P. purpurogenum was highly resistant to cadmium and copper.

The above mentioned observations might be attributed to one or more of the following facts :

- i. Cultivation of soybean or corn plants variably influenced growth of microorganisms dependent on quality and quantity of their root exudates.
- ii. The low frequency of some organisms might be attributed to their sensitivity towards the toxicity of cadmium ions supplemented to the soil (Gingell et al., 1976 Cenci and Morozzi, 1977; Imagawa et al., 1981).
- iii. The dominance or prevalence of other groups of fungi may be explained on the basis of tolerance and/or resistance to the deleterious effects of cadmium; a phenomenon already reported by several investigators (Ashida, 1965 ; Turner, 1969 ; Tatsuyama et al., 1975a,b; Babich and Stotzky, 1977a).

According to the response to cadmium, Babich and Stotzky (loc.cit.) grouped the mycelial fungi into three broad

categories; the first group was capable of growth in presence of 10 ug/ml. but was inhibited by 100 ug/ml. the second group grew at 100 ug/ml. but was inhibited by 1000 ug/ml. and the third group grew at 1000 ug/ml. They included Trichoderma viride and Rhizopus stolonifer in the third group.

iv. Root exudates are a function of plant age and/or season. This reflects its effect on the rhizosphere fungi causing stimulation or suppression of growth of one or several of the prevailing organisms.

From the above mentioned discussion it appears that supplementation of soils with cadmium sulphate or cadmium nitrate induced a significant drop in the total number of fungi in the rhizosphere of growing soybean and corn plants. Due to the selective action or selective response to cadmium the number of some types and groups of fungi was highly attenuated whereas others appreciably increased in number or were totally indifferent to cadmium. Such disturbance in microfloral structure of the soil will induce changes in suitability of such soil to the growth of certain crop plants.

Concerning the effect of cadmium salts on some growth criteria of the fungi, experimented with, the results revealed that the response of spore germination to cadmium salts

is not a function of tolerance of the organism to this metal ion. This is quite obvious from the fact that 1000 ppm arrested spore germination in the most resistant (Rhizopus) and most sensitive (Cladosporium) fungus but caused 50% inhibition of Curvularia (moderately tolerant.) and Fusarium (sensitive). Smaller cadmium doses seemed without effect except on Aspergillus (highly tolerant) and Paecilomyces (moderately tolerant) that were stimulatory; more prominently with nitrate accompanying cadmium as its anions.

The results of spore germination further show that cadmium at 50-100 ppm did not affect spore germination of the very active germinating organisms (Curvularia, Fusarium and Rhizopus) whereas spore germination of moderately active or slow germinating organisms was either stimulated or inhibited, dependent on the sensitivity of the organisms to cadmium. Inhibition was apparent in the very sensitive organisms (Cladosporium) while stimulation was observed in the sensitive or moderately tolerant organisms. This points to the interaction between cadmium and permeability of the spore wall and/or germ tube as a function of period of contact (germination period).

In this connection it may be mentioned that Ross (1982) noticed that 7.5-10 μM cadmium almost completely suppressed germination of Candida albicans spores. No mycelial development occurred.

The results further show that inspite of the fact that the six selected fungi could, in one way or the other, tolerate the presence of cadmium in the soil up to 1000 ppm yet when cultured on Dox or potato dextrose media they could not appreciably grow at such high level of cadmium. Still the largest dose (500 ppm) seemed highly deleterious. It arrested growth of Aspergillus terreus (highly tolerant) and reduced dry weight gain of the other three surviving fungi to 50 % or even less than that of controls; more prominently with sulphate as the accompanying anion. This might be due to better utilization of nitrate than sulphate thus rendering the medium more acidic, with sulphate, thus helping in better permeation of cadmium into the fungal cells.

Still Paecilomyces divaricata (moderately tolerant) and Cladosporium herbarum (sensitive) were unable to grow in potato dextrose media containing 50 ppm cadmium.

These discussions indicate that the observed tolerance or sensitivity of these fungi to cadmium were not inherent to the organisms but due to other coherent factors such as nature of the soil and type of its clay and/or organic matter content both of which play a great role in chelation and ion exchange mechanisms for cations particularly those of heavy metals.

In this connection, it may be mentioned that Weber and Poselt (1974) reported that cadmium can form stable complexes with naturally occurring organics whereas Hem (1972) stated that the amount of cadmium occurring in organic complexes was generally small and that this element was less tightly bound than zinc by almost organic ligands. Pittwell (1974) reported that cadmium would be complexed by organic carbon under all pH conditions encountered in normal natural waters. Levi-Minzi et al., (1976); Pinskii (1981) found cadmium sorption in soils to be correlated with soil organic matter content.

Moshe et al., (1972) found that cadmium at 1mg/l. was toxic to algae in laboratory experiments whereas 6 mg/l. in oxidation ponds had no effect. This negative effect was attributed to high pH, in the ponds, which caused the metal ions to precipitate as hydroxides. Babich and Stotzky (1977 b) concluded that clay minerals protected fungi against cadmium toxicity. This was ascribed to the cation exchange capacity of such minerals. This was further confirmed by the observation that clay which was homoionic for cadmium was extremely toxic to the fungi when they were grown on nutrient agar, since cadmium was then itself exchanged and was toxic to the fungi. In the meantime Elliott and Denney (1982) reported that organic complexation increased or had little precipitable effect on

cadmium adsorption onto 3 soils from the northeastern US when compared to unbound cadmium. Still, Gjessing (1981) showed that cadmium toxicity to salmon and algae was considerably reduced when humus was added to the water.

Furthermore, it seems that in artificial media, Rhizopus oryzae was most tolerant to both cadmium salts (the dry weight gain being noticeably reduced only at 500 ppm) followed by Fusarium oxysporum whereas Aspergillus terreus was most sensitive.

It should be recalled that Babich and Stotzky (1977 a) classified Rhizopus stolonifer and Trichoderma viride as highly tolerant to cadmium, being able to grow at 1000 ug/ml. of the ion. Aspergillus niger was classified moderately tolerant as it was capable of growing at 100 ug/ml. but inhibited at 1000 ug/ml. Naplekova (1982) reported that Alternaria tenuis showed an increased tolerance to cadmium while Macaskie and Dean (1982) showed that no mold could grow in less than 4 days, in cadmium medium whether these were isolated from polluted or non polluted soils. Ross (1982) demonstrated that $\leq 5 \mu\text{M}$ cadmium was strongly inhibitory to growth of Candida albicans.

It is interesting to note that nitrogen secretion by Aspergillus terreus, Curvularia tetramera and Fusarium oxysporum increased with increased concentration of cadmium, almost to the same extent regardless of the accompanying anion except for Aspergillus where sulphate highly stimulated such process.

On the other, hand, up to 100 ppm, cadmium slightly, if at all, affected wherase 1000 ppm largely enhanced nitrogen secretion by Rhizopus oryzae. This indicates that nitrogen secretion by these fungi, was not a function of their tolerance to cadmium but largely controlled by the effects of cadmium on permeability of the mycelial cells of each individual fungus. Regardless of the largest dose which was toxic to the four fungi, the smaller doses seemed to have no effect on permeability of Rhizopus cells but remarkably increased permeability of the other three fungi, particularly Aspergillus terreus.

It may be worth noting that Hutchinson and Czyrska (1975) suggested that cadmium affected the feedback control of permease systems that transported phosphate (or silicate) into the cells of Asterionella formosa. Li (1978) reported that cadmium interacted with the phospholipid monolayers, implying that it may have a toxic effect on biological membranes.

Since the main bulk of increased nitrogen secretion was in the peptide component one may conclude that cadmium impaired the transforamtion of peptides to true proteins. Still the large amounts of secreted other soluble nitrogen with supplementation of the largest dose of cadmium indicates that the toxic doses of the metals also inhibited the incorporation of the absorbed nitrates into amino acids.

Results of mycelial analysis add further evidence in support of the suggestion that the accompanying anion played a significant role regarding the response of fungi to cadmium. Cadmium nitrate-treated mycelia of the four fungi showed higher levels of total nitrogen compared with cadmium sulphate treatment. In the meantime though Aspergillus terreus seemed most sensitive to cadmium yet it accumulated the largest percentage of nitrogen compared with its control, particularly with 100 ppm cadmium administration whereas Curvularia tetramera showed the least nitrogen content. Mycelial nitrogen of Rhizopus oryzae seemed indifferent to cadmium, most prominently as cadmium nitrate.

Apparently cadmium seemed to stimulate nitrogen metabolism of Fusarium oxysporum, even at 500 ppm cadmium nitrate but most of the accumulated nitrogen was in the amino and other soluble forms indicating a slow rate of transformation of amino acids to peptides. In the meantime, accumulation of these two components in either Aspergillus or Fusarium might explain the low toxicity of absorbed cadmium, by both fungi, most probably through complexing with these components. On the other hand, the sensitivity of nitrogen metabolism of Rhizopus to cadmium treatment might be attributed to larger amounts of other insoluble nitrogen (cell wall nitrogen) which might oppose and hinder permeation to cadmium; a phenomenon that was lacking

in Curvularia where other soluble nitrogen was also lower than the controls. Both features might allow for accumulation of enough inorganic cadmium to exert apparent metabolic disorders.

It is worth mentioning that Byrne et al., (1976) noticed that cadmium accumulated to a surprising extent in several fungi. Friberg et al., (1974), Hampp et al., (1976) observed a strong affinity of cadmium for side chain ligands of proteins; an indication that the element highly interferes with enzymatic activities. Payer and Runkel (1978) reported that mercury and cadmium are present as inorganic forms as well as chemically bound to organic metabolites within algal cells. Shibata (1977), Rugstad and Norseth (1978) confirmed the accumulation of cadmium in liver, kidney and pancreas in the form of thionine-metal complex. Similarly metallothionine-like proteins were reported by Hart and Bertram (1980) as a mechanism of tolerance of Chlorella pyrenoidosa against large doses of cadmium. Aiking et al (1982) noticed that cadmium content of Klebsiella aerogenes was proportional to inorganic sulphide content. This suggested that formation of cadmium sulphide as probably the most important mechanism for detoxification.

It is interesting to note that the stimulated nitrogen accumulation in Fusarium or inhibited nitrogen metabolism

in Curvularia were accompanied by similar initiation and suppression of polysaccharide synthesis. On the other hand, cadmium did not affect the polysaccharide content of Aspergillus terreus but increased that of Rhizopus oryzae though nitrogen metabolism was enhanced in the former and slightly, if at all, suppressed in the latter organism. .

These observations indicate that retardation of growth of Aspergillus or Curvularia by cadmium was not the result of metabolic disorders but due to dramatic effects of the cation on cell division and/or RNA, or DNA content of the organisms. Stimulation of polysaccharide accumulation seemed to be another mechanism for detoxification of cadmium by Rhizopus and Fusarium. Still nucleoprotein nitrogen decreased with cadmium administration to the four fungi, more prominently at the large doses of the ion.

According to Rosko and Rachlin (1977), the effective concentrations of cadmium, copper, mercury and zinc respectively that caused 50% depression of cell division of Chlorella vulgaris were 0.06, 0.18, 1.03 and 5.10 mg/L. Under all tested cation concentrations. Chlorella was able to overcome the stress and resume some cell division with lapse of time. Such reduced cell division was always accompanied by increased chlorophyll 'a' content i.e, increased carbohydrate synthesis.

Vorob'eva et al., (1979) reported that low concentrations of cadmium and zinc stimulated photosynthesis in Chlorella pyrenoidosa. Anikeeva et al., (1975) and Kogan et al., (1975) reported that cadmium had a negative effect on Chlorella culture; the growth rate and viability of cells decreased, disturbing their division and resulting in increased rate of speckled cells. Sina and Chin (1978) reported that exposure of the acellular slime mold Physarum polycephalum to cadmium resulted in distortion of nuclear structure and inhibition of RNA synthesis. Nakano et al (1978) reported that cadmium was neither involved in normal cell metabolism of Euglena gracilis, under zinc deficiency nor did it replace zinc which is essential for growth.

It is interesting to note that the increased nitrogen and polysaccharide accumulation, following cadmium administration to Fusarium oxysporum was accompanied by a concomitant lowering of the total phosphorus content; more prominently in the inorganic and insoluble components. In the meantime, the amino and other soluble were mainly responsible for the increased nitrogen content. This confirms the possible impairment of protein synthesis as a result of lower nucleoproteins nitrogen as well as confirmed by low insoluble phosphorus. The increasing levels of inorganic phosphorus and/or soluble organic phosphorus in Aspergillus terreus coupled with low

protein and high amino nitrogen indicates the incapability of the fungus-under cadmium stress-to incorporate the absorbed phosphorus into energy rich compounds (as components of soluble organic phosphorus) and thus amino acids failed to polymerise to proteins, inspite of large accumulations of nitrogen in the mycelia.

On the other hand, cadmium-treated Curvularia tetramera accumulated the largest amounts of phosphours (among the four fungi) mostly in the insoluble form whereas the inorganic component was less than that of the control level. In the meantime, nucleoprotein nitrogen seemed unaffected. Accordingly it seems that the lower nitrogen content of this fungus(following cadmium treatment) was the result of lower carbon supply (decreased polysaccharide content) and/or lower retention of absorbed nitrate nitrogen or its assimilates in the mycelia. In case of Rhizopus oryzae, most of the increased phosphorus uptake, accumulated in the soluble organic forms whereas the insoluble and/or inorganic phosphorus levels were slightly, if at all, affected. This denotes increased metabolic activity which reflected itself mostly in polysaccharide accumulation, with slight decrease of total nitrogen.

It is worth mentioning that Lee et al., (1976) noticed that cadmium-treated soybean leaves showed higher respiration

rate and activities of malate dehydrogenase, acid phosphatase, ribonuclease and deoxyribonuclease. Zasukhina et al., (1977) reported that cadmium chloride caused degradation of DNA in human and rat embryo cells. Ivashchenko (1978) reported increased ATP-ase activity of rat heart mitochondria whereas Matsumoto et al (1977) reported inhibited ATP-ase activity in pig intestinal smooth muscle, following cadmium administration. De Filippis et al (1981) attributed the low photosynthetic activity of zinc-, cadmium-, and mercury-treated Euglena to severe interaction of these metals with the electron transport chain; water splitting site, and oxidoreductase being the most sensitive steps.

Generally speaking, cadmium initiated organic acid secretion in the media of the four tested fungi. Within the limits of non toxic concentrations (50-100 ppm) cadmium largely accelerated organic acid secretion by sensitive fungi (Aspergillus and Curvularia) compared with the more tolerant organisms (Rhizopus and Fusarium).

From the above discussion it seems that tolerance or sensitivity of the fungi to cadmium treatment is the cumulative result of the effect of this ion on the various metabolic activities of each individual fungus. Soil structure particularly

the organic carbon and/or type of clay particles play a significant role in such phenomena.

S U M M A R Y

SUMMARY

This investigation was planned to study the effect of soil treatment with either cadmium sulphate or cadmium nitrate on the prevalence of rhizosphere fungal flora of soybean and corn in RAE. It is also intended to find out possible explanations for the observed variations in microfloras in terms of sensitivity or tolerance of these microorganisms to cadmium ion. The results could be summarized as follows :

1. 8161 fungal isolations were identified and were found to represent 47 species belonging to 27 genera.
2. Aspergilli represented the group of fungi of highest frequency of occurrence under the different experimental conditions. It represented almost one half of the total number of isolations of the rhizospheric fungi. Aspergillus niger revealed the highest frequency of occurrence and density.
3. The remaining isolated groups can be arranged in the following descending order according to their frequent occurrence :
Moniliaceae (excluding Aspergillus and Penicillium),
Phycomycetes, Dematiaceae, Mycelia sterilia, Ascomycetes,
Fusarium spp. and Penicillium spp.

4. The total number of fungal genera and species, isolated from samples collected from treated soils with cadmium sulphate or cadmium nitrate was found to be lower than that isolated from samples collected from cadmium-free soils. The possible explanations for such variations were discussed.
5. The nature and type of the test plant had a prominent effect on the total count of its rhizosphere fungi. Soybean supported, under different treatments, statistically lower total counts in its rhizosphere than corn.
6. Soil treatment with different doses of cadmium sulphate or cadmium nitrate resulted in a statistically significant reduction in the total number of population in the soil. Yet, such effect was a result of clear reduction in the numbers of some types and groups of fungi while other types and groups either behaved indifferently to the cadmium ion or even revealed an increase in their numbers in presence of cadmium. The importance of this observation in studies of the effect of heavy metals on microorganisms was discussed.
7. The observed tolerance or sensitivity of the test fungi to cadmium were not inherent but due to other coherent factors such as nature of soil and type of its clay and/or

organic matter content.

8. Nitrogen secretion by the test fungi was not a function of their tolerance to cadmium but largely controlled by the effects of cadmium on permeability of the mycelial cells of each individual fungus.
9. Cadmium seemed to stimulate nitrogen metabolism of Aspergillus and Fusarium, but most of the accumulated nitrogen was in the amino and other soluble forms. The accumulation of enough inorganic cadmium in some of the fungi experimented with exerted apparent metabolic disorders.
10. Cadmium inhibited the incorporation of the absorbed phosphorus into energy rich compounds which were concomitant by failure of amino acid polymerization to proteins.
11. Cadmium initiated organic acid secretion in the media of the four tested fungi.

REFERENCES

- AHMED, A.M. and RIES, E. (1969) :
The pattern of $^{14}\text{CO}_2$ fixation in the different phases of the life cycle and under different wave lengths in Chlorella pyrenoidosa. Progress in Photosynthesis Research. 3: 1662.
- AIKING, H. ; KOK, K. ; VAN HEERIKHUIZEN, H. and VAN'T RIET, J. (1982):
Adaptation to cadmium by Klebsiella aerogenes growing in continuous culture proceeds mainly via formation of cadmium sulphide. Appl. Environ. Microbiol. 44 : 938-44.
- ALI, M.I. (1977) :
On the fungal flora of Saudi Arabia 1. Wadi Hanifa. Bull. Fac. Sci., Riyadh Univ., 8 : 7-20.
- AL-WAKIL, SH.A. (1981) :
Response of crop plants to various cadmium treatments. Ph. D. Thesis. Bot. Dep. Fac. Sci. Cairo Univ.
- AMES, L.A. (1969) :
A monograph of the Chaetomiaceae. Wheldon and Wesley, L.T.D. Stechert-Hanser Service Agency, Inc. Codicte, Herets. New York, N.Y.
- ANIKEEVA, I.D. ; VAULINA, E.N. and KOGAN, I.G. (1975) :
Effect of cadmium ions on Chlorella : 1-growth, survival and mutability of Chlorella. Genetica 11 : 78-83.
- ANTONOVICS, J. ; BRADSHAW, A.D. and TURNER, R.G. (1971) :
Heavy metal tolerance in plants. Advances in Ecological Research 7 : 1-85.
- VASHIDA, J. (1965) :
Adaptation of fungi to metal toxicants. Annual Review of Phytopathology 3: 153-174.
- BABICH, H. and STOTZKY, G. (1977a) :
Sensitivity of various bacteria, Including Actinomycetes, and fungi to cadmium and the influence of pH on sensitivity. Appl. Environ. Microbiol. 33(3): 681-685.
- BABICH, H. and STOTZKY, G. (1977 b):
Reductions in the toxicity of cadmium to microorganisms by clay minerals. Appl. Environ. Microbiol. 33(3) : 696-705.

- BARNETT, H.L. and HUNTER, B.B. (1972) :
Illustrated genera of imperfect fungi.
Burgess publishing company. Minneapolis. PP.
241.
- BARRON, G.L. (1968) :
The genera of Hyphomycetes from soil. Williams
and Wilkins Co. : Baltimore.
- BARTOLF, M., BRENNAN, E. and PRICE, C.A. (1980) :
Partial characterization of a cadmium-binding
protein from the roots of cadmium-treated tomato
Plant Physiol. 66 : 438-441.
- BOOTH, C. (1977) :
The genus Fusarium. Commonwealth Mycological
Institute, Kew, Surrey, England.
- BROWN, A.H.S. and SMITH, G. (1957) :
The genus Paecilomyces Bainier and its perfect
stage Byssochlamys Westting. Trans. Br. Mycol.
Soc. 40 : 17-89.
- BROWN, T.A. and SMITH, D.G. (1980) :
Effects of cadmium chloride on the growth and
ultrastructure of Cryptococcus albidus. Micro-
bios. Lett, 13 (51/52) : 157-164. 1
X
ces
- BURNISON, G. ; WONG, P.T.S. ; CHAU, Y.K. and SILVERBERG,
B.A. (1975):
Toxicity of cadmium to freshwater algae. Proc.
Canad. Fed. Biol. Sci. Winnipeg 18 : 182.
- BURTON, J.O. and RILEY, J.P. (1954) :
In " Modern methods of plant analysis ", by Paech,
K. and Tracey, M.V. (1955): Vol. 2, P. 370,
Springer Verlag, Berlin.
- BURZYNSKA, H. and MACIEJSKA, K. (1978) :
The effect of some contaminants occurring in food
on the growth of Aspergillus flavus and the pro-
duction of aflatoxins. Acta. Aliment. Pol.,
4: 119-128.
- BYRNE, A.R. ; RAVNIK, V. and KOSTA, L. (1976) :
Trace element concentrations in higher fungi.
Sci. Total Environ. 6 : 65-78.

- CARROLL, R.E. (1966) :
The relationship of cadmium in the air to cardiovascular disease death rates. J. Amer. Med. Assoc. 198 : 267-269.
- CENCI, G. and MOROZZI, G. (1977) :
Evaluation of the toxic effect of Cd^{2+} and $\text{Cd}(\text{CN})_4^{2-}$ ions on the growth of mixed microbial population of activated sludges. Sci. Total Environ. 7(2): 131-143.
- ✓ CHANEY, A.L. and MARBACH, E.P. (1962) : Modified reagents for determination of urea and ammonia. J. Clin. Chem., 8 : 130-132.
- CHUECA, A.C., GARCIA DEL AMO and RUIS, A. (1971) :
Interference of cadmium on the turn-over of zinc orally administered. Rev. Esp. Fisiol, 27 : 143 : 148.
- COCHRANE, V.W. (1958) :
Physiology of Fungi. John Wiley and Sons, Inc. London.
- COUSINS, R.J., BARBER, A.K. and TROUT, J.R. (1973) :
Cadmium toxicity in growing swine. J. Nutr. 103 : 964-972.
- CROESSMANN, G. and EGELS, W. (1975) :
Research concerning the cadmium contents in single feedstuffs. Landwirtsch. Forsch 28(2) : 164-173.
- ✓ DE FILIPPIS, L.F. ; HAMPP, R. and ZIEGLER, H. (1981) :
The effects of sublethal concentrations of zinc, cadmium, and mercury on Euglena : 2-Respiration, photosynthesis and photochemical activities. Arch. Mikrobiol. 128 : 407-411.
- DEKOCK, P.C. (1956) :
Heavy metal toxicity and iron chlorosis. Ann. Bot., 20 : 133-141.
- ELLIOTT, H.A. and DENNENY, C.M. (1982) :
Soil adsorption of cadmium from solutions containing organic ligands. J. Environ. Qual. 11 : 658-663.
- ELLIS, M.B. (1971) :
Dematiaceous Hyphomycetes. Commonwealth Mycol. Inst., Kew, Surrey, England.

- ELLIS, M.B. (1976) :
More Dematiaceous Hyphomycetes. Commonwealth
Mycol. Inst., Key, Surrey, England.
- ERNST, W. (1972) :
Zinc and cadmium pollution of soils and plants
in the vicinity of a zinc smelting plants. Ber
Dtsch. Bot. Ges. 85 : 295-300.
- FATHI, S.M. ; El- HUSSEINI, T.M. ; ABU-ZINADA, A.H. (1975):
Seasonal variations of soil microflora and
their activities in Riyad region, Saudi Arabia.
Bull. Fac. Sci., Riyad Univ. 7 : 17-30.
- FAWCETT, J.K. and SCOTT, J.E. (1960) :
A rapide and precise method for determination
of urea. J. Clin. Path., 13 : 156-159.
- FRIBERG, L. ; PISCATOR, M. ; NORDBERG, G.F. and KJELLSTRÖM,
T. (1974):
Cadmium in the environment. The chemical Rubber
Company Press. Cleveland, Ohio.
- GACHTER, R. (1976) :
Untersuchungen über die Beerinflussung der
planktischer durch anorganische Metallsalze im
eutrophen Alpnersee und der mesotrophen
Hornerbucht. Schweiz. Z. Hydrol. 38 : 97-119.
- GARRETT, S.D. (1946) :
A study of violet root rot. Factors affecting
production and growth of mycelial strands in Hel-
icobasidium purpureum. Pot. Trans. Br. Mycol.
Soc. 29 : 114-127.
- GARRETT, S.D. (1963) :
A comparison of cellulose decomposing ability
in five fungi causing cereal root rots. Trans.
Brit. Mycol. Soc., 46 : 572-576.
- GJESSING, E.T. (1981) :
The effect of aquatic humus on the biological
availability of cadmium. Arch. Hydrobiol.
91: 144-9.
- GILMAN, J.C. (1957) :
A manual of soil fungi. Iowa, State Univ. Press,
Ames. Iowa, U.S.A.

- ✓ GINGELL, S.M. ; CAMPBELL, R. and MARTIN, M.H. (1976) :
The effect of zinc, lead and cadmium pollution
on the leaf surface microflora. Environ
Pollut 11(1): 25-37.
- ✓ GUNN, S.A., GOULD, T.C. and ANDERSON, W.A. (1963) :
Cadmium induced interstitial cell tumors in
rats and mice and their prevention by zinc. J.
Nat. Cancer Inst. 31 : 745-759.
- ✓ HAMPP, R. ; BEULICH, K. and ZIEGLER, H. (1976) :
Effects of zinc and cadmium on photosynthetic
carbon dioxide fixation and Hill activity of
isolated spinach chloroplasts. Z. Pflanzenphysiol.
77 : 336-344.
- ✓ HART, B.A. and BERTRAM, P.E. (1980) :
A cadmium binding protein in a cadmium tolerant
strain of Chlorella pyrenoidosa. Environ. Exp.
Bot. 20 : 175-180.
- ✓ HEM, J.D. (1972) :
Chemistry and occurrence of cadmium and zinc in
surface water and ground water. Water. Resour.
Res. 8 : 661-679.
- ✓ HEWITT, E.J. (1953) :
Metal interrelationships in plant nutrition-1-
Effects of some metal toxicities on sugar beets,
tomato, oat, potato and marrow stem kale grown
in sand culture. J. Expt. Bot., 4 : 59-64.
- HOUBA, C. and REMACLE, J. (1980) :
Composition of the saprophytic bacterial communi-
ties in freshwater systems contaminated by heavy
metals. Microb. Ecol. 6(1) : 55-69 (Eng.).
- ✓ HUTCHINSON, T.C. and CZYRSKA, H. (1975) :
Heavy metal toxicity and synergism to floating
aquatic weeds. Verh. Int. Ver. Limnol. 19 :
2102-2111.
- IMAGAWA, M.; NISHIHARA, T. ; ICHIKAWA, T. and KONDO, M.
(1981):
Effect of cadmium chloride on growth and some
enzyme activities of Bacillus megaterium QMB
1551. Eisei Kagaku 26(6): 302-306.

- IVASHCHENKO, A.T. (1978) :
Anion-sensitive ATP-ase of rat heart mitochondria.
Tsitologiya 20 : 113-117.
- JACKSON, M.L. (1967) :
Soil chemical Analysis. Printice. Hell of
India Private New Delhi.
- JENSEN, H.L. (1931) :
The fungus flora of the soil. Soil Sci., 31 :
123-58.
- JOHNSON, L.F. (1957) :
Effect of antibiotics on the numbers of bacteria
and fungi isolated from soil by the dilution
plate method. Phytopathology. 47 : 630-631.
- JOHNSON, L.F. ; CURL, E.A. ; BOND, J.H. and FRIBOURG, H.A.
(1960):
Methods for studying soil microflora-plant disease
relationships. Burgess Publishing Company. Minn-
eapolis PP. 178.
- KEEN, B.A. and RACZKOWSKI, H. (1921) :
The relation between the clay content and certain
physical properties of a soil. J. Agric. Sci.,
11 : 441-449.
- KOGAN, I.G. ; ANIKEEVA, I.D. and VAULINA, E.N. (1975) :
Effect of cadmium ions on chlorella : 2. Modifi-
cation of the UV-irradiation effect. Genetica,
11: 84-88.
- KNEIP, T.J. (1978) :
Effect of cadmium in an aquatic environment.
In Proceedings of the first International cadmium
conference. San Francisco, Jan. 1977 PP. 120-124.
- LAGERWERFF, J.V. (1972) :
Lead, mercury, and cadmium as environmental con-
taminants. In Micronutrients in agriculture.
Edited by J.J. Mortvedt et al., Soil Sci. Soc.
Am., Madison. WI. PP 593-636.
- LEE, K.G. ; CUNNINGHAM, B.A. ; PAULSEN, G.M. ; LIANG, G.H.
and MOORE, R.B. (1976):
Effects of cadmium on respiration rate and activ-
ities of several enzymes in soybean seedlings.
Physiol. Plant-36: 4-6,

- ✓ LEVI-MINZI, R. ; SOLDATINI, G.F. and RIFFALDI, R. (1976):
Cadmium absorption by soils. J. Soil. Sci. 27 :
10 - 15.
- ✓ LI, W.K.W. (1978) :
A kinetic analysis of the interactive effects
of cadmium and nitrate on phytoplankton growth.
In proceedings of 41st Annual Meeting of the
American Society on Limnology and Oceanography,
Univ. of Victoria, B.C.
- LILLEHOJ, E.B. ; GARCIA, W.J. and LAMBROW, M. (1974) :
Aspergillus flavus infection and aflatoxin pro-
duction in corn: Influence of trace elements.
Appl. Microbiol, 28(5): 763-767.
- LOBYREVA, L.V. (1973) :
Effect of metal ions on lypolytic activity of
the yeast, Candida utilis 295.t. 12v Akad
Nauk SSSR Otd Biol. Nauk, 4: 581-584.
- ✓ LOWRY, O.H.; ROSENBROUGH, J. ; FAN, A.C. and RANDAL, R.J.
(1951):
Protein measurement with folin phenol reagent. J.
Biol. Chem., 193 : 265-275.
- MACASKIE, L.E. and DEAN, A.C.R. (1982) :
Cadmium accumulation by microorganisms. Environ.
Technol. Lett, 3 : 49-56.
- MALONE, C.P., MILLER, R.J. and KOEPPE, D.E. (1978) :
Root growth in corn and soybeans : Effects of
cadmium and lead on lateral root initiation.
Can. J. Bot. 56 : 277-281.
- ✓ MARSH, P.B. ; SIMPSON, M.E. and TRUCKSESS, M.W. (1975) :
Effect of trace metals on the production of afl-
atoxins by Aspergillus parasiticus. Microbiol,
30 : 52-57.
- MARTIN, J.P. (1950) :
Use of acid rose bengal and streptomycin in the
plate method for estimating soil fungi. Soil.
Sci., 69 : 215-233.
- MARTIN, H. (1969) :
Inorganics, P. 101: 117, In D.C. Torgeson (ed.),
Fungicides : an advanced treatise, Vol.2. Academic
Press. Inc., New York.

- MATSUMOTO, H. ; YABU, H. and MIYAZAKI, E. (1977) :
Effects of some divalent and trivalent cations on the ATP-ase activity. Ca^{2+} -binding of myosin B extract from pig intestinal smooth muscle. Sapporo Med. J. 46 : 167-170.
- ✓ MILLER, R.J. ; BITTELL, J.E. and KOEPPE, D.E. (1973) :
The effect of cadmium on electron and energy transfer reactions in corn mitochondria. Physiol. Plant., 28 : 166-171.
- MOSHE, M. ; BETZER, N. and KOTT, Y. (1972) :
Effect of industrial wastes on oxidation pond performance. Water Res. 6 : 1165-1171.
- MOUBASHER, A.H. and EL DOHLOB, S.M. (1970) :
Seasonal fluctuations of Egyptian Soil fungi. Trans. Br. Mycol. Soc., 54 : 45-51.
- MOUBASHER, A.H. and MOUSTAFA, A.F. (1970) :
A survey of Egyptian soil fungi with special reference to Aspergillus, Penicillium and penicillium-related genera. Trans. Br. Mycol. Soc., 54 : 35-44.
- ✓ NAGUIB, M.I. (1964) :
Effect of sevin on the carbohydrate and nitrogen metabolism during germination of cotton seeds. Indian J. Expt. Biol., 2 : 149-152.
- NAUGIB, M.I. (1969) :
On the colorimetry of nitrogen components of plant tissues. Bull. Fac. Sci. Cairo Univ., 43 : 1-5.
- NAIM, M.S. (1967 b) :
Contribution to the knowledge of soil fungi in Libya. 11. Fungus flora under Citrus trees in Libya. Mycopathol. Mycol. Appl., 31 : 296-299.
- NAKANO, Y. ; OKAMOTO, K. ; TODA, S. and FUWA, E. (1978) :
Toxic effects of cadmium on Euglena gracilis grown in zinc deficient and zinc sufficient media. Agric. Biol. Chem., 42 : 901-908.
- NAPLEKOVA, N.N. (1982) :
Effect of salts of some heavy metals on the physiological activity of cellulose-decomposing microorganisms. Izv. Sib. Otd. Akad. Nauk SSSR. Ser. Biol. Nauk, 2 : 79-85.

- NELSON, N. (1944) :
A photometric adaptation of Somogyi method for
the determination of glucose. J.Biol . Chem.,
153 : 375-380.
- NORDBERG, G.F. and PISCATOR, M. (1971) :
Effect of acute and chronic cadmium exposure
on the testicles of mice. Environ. Physiol.
Biochem. 1: 171.
- NORDBERG, G.F. ; NORDBERG, M. ; PISCATOR, M. and VESTERBERG,
D. (1972):
Separation of two forms of rabbit metallothioneine
by isoelectric focusing. Biochem. J. 126 :
491-498.
- NOUR, M.A. (1956) :
A preliminary survey of fungi in some sudan Soils.
Trans. Brit. Mycol. Soc. 39 : 357-360.
- NRIAGU, J.O. (1980) :
Cadmium toxicity to phytoplankton and microor-
ganisms. In J.O. NRIAGU Ed., Cadmium in the enviro-
nment. Part 1, Ecological Cycling, A Wiley-
Interscience Publication. John Wiley and Sons.
New York, Chichester Brisbane. Toronto.
- ✓PAGE, A.L. ; BINGHAM, F.T. and NELSON, C. (1972) :
Cadmium absorption and growth of various plant
species as influenced by solution cadmium con-
centration. J. Environ. Qual. 1 : 288-292.
- PASSOW, H. ; ROTHSTEIN, A. and CLARKSON, T.W.(1961):
The general pharmacology of the heavy metals.
Pharmacological Reviews, 13 : 185-224.
- ✓PAYER, H.D. and RUNKEL, K.H. (1978) :
Environmental pollutants in fresh water algae from
open air mass cultures. Arch. Hydrobiol. Beih.
Ergebn. Limnol. 11 : 184-198.
- PERRY, H.M., JR. (1968) :
Hypertension and trace metals, with particular em-
phasis on cadmium. Proc. 2nd. Ann. Conf. Trace
Subst. Environ. Health; Univ. of Missouri,
Columbia, Mo. PP. 101-125.

- PERRY, H.M., JR. ; TIPTON, I.H. ; SCHROEDER, H.A. ; STEINER, R.L. and COOK, M.J. (1961):
Variation in the concentration of cadmium in human kidney as a function of age and geographic origin. J. Chronic Dis. 14 , : 259-271.
- PETIT, C.M.; RINGOET, A. and MYTTENAERE, C. (1978) :
Stimulation of cadmium uptake in relation to the cadmium content of plants. Plant Physiol. 62 : 554-557.
- PICKETT, A.W. and DEAN, A.C.R. (1976) :
Cadmium and zinc sensitivity and tolerance in Klebsiella (Aerobacter) aerogenes. Microbios 15 (60): 79-91.
- PIETILAINEN, K. (1975) :
Synergistic and antagonistic of lead and cadmium on aquatic primary production. Int. Conf. on Heavy Metals in the Environment. Symposium Proc., 2 (Pt.2) : 861-873.
- PINSKII, D.L. (1981) :
Sorption of heavy metals by soils. Deposited Doc. Viniti 5588 : 81-87.
- PITTWELL, L.R. (1974) :
Metals coordinated by ligands normally found in natural waters. J. Hydrobiol. 21 : 301-304.
- RAPER, K.B. and FENNELL, D.L. (1965) :
The genus Aspergillus. Williams and Wilkins. Baltimore U.S.A. PP. 876.
- RAPER, K.B. and THOM, C. (1949) :
A manual of the Penicillia. Williams and Wilkins Baltimore, U.S.A., PP. 875.
- RIKER, A.J. and RIKER, R.S. (1936) :
Introduction to research on plant diseases. John. Swift and Co., St. Louis, Mo.
- ROSKO, J.J. and RACHLIN, J.W. (1977) :
The effect of cadmium, copper, mercury, zinc and lead on cell division, growth and chlorophyll a content of chlorophyte Chlorella vulgaris. Bull. Torrey Bot. Club. 104 : 226-233.
- ROSS, I.S. (1982) :
Effect of copper, cadmium and zinc on germination and mycelial growth in Candida albicans. Trans. Br. Mycol. Soc. 78 : 543-5.

ROUATT, J.W. ; PETERSON, E.A. ; KATZNELSON, H. and HENDERSON, V.E. (1963):

Microorganisms in the root zone in relation to temperature. *Canad. J. Microbiol.*, 9 : 227.

ROVIRA, A.D. (1959) :

Root excretion in relation to the rhizosphere effect. IV Influence of plant species, age of plant, light, temperature and calcium nutrition on exudation. *Plant and Soil*, 11 : 53.

RUGSTAD, H.E. and NORSETH, T. (1978) :

Cadmium resistance and content of cadmium-binding protein in 2 enzyme deficient mutants of mouse fibroblasts (L-Cells). *Biochem. Pharmacol.* 27 : 647-50.

RUSSELL, J.A. (1944) :

Note on the colorimetric determination of amino nitrogen. *J. Biol. Chem.*, 156 : 467-468.

SABBIONI, E. and MARAFANTE, E. (1975) :

Heavy metals in rat liver cadmium binding protein. *Environ. Physiol. Biochem.* 5 : 132-141.

SABET, Y.S. (1935) :

A preliminary study of the Egyptian soil fungi. *Bull. Fac. Sci. Egyptian Univ.*, 5: 1-12.

SAID, A., and NAGUIB, M.I. (1964) :

Sucrose determination as a means of estimation of the " Draw Back Tax " of Halawa Tehinia. *Bull. Fac. Sci. Cairo Univ.* 39 : 207.

SCHMIDT, O. and ZIEMER, B. (1976) :

On preservative tolerance in fungi. *Mater Ore*, (Berl) 11(3): 215-230.

SCHROEDER, H.A. (1965) :

Cadmium as a factor in Hypertension. *J. Chronic Dis.* 18 : 647-656.

SCHROEDER, H.A. and BALASSA, J.J. (1961) :

Abnormal trace metals in man : Cadmium. *J. Chronic Dis.* 14 : 236-258.

SHAIKH, Z.A. and LUCIS, O.J. (1970) :

Induction of cadmium binding protein. *Fed. Proc.* 29 : 301.

SHIBATA, H. (1977) :

Whole body autoradiographic studies on the fate of zinc, cadmium and mercury in mice. Bull. Fac. Agric. Yamaguti. 28 : 83-98.

✓ SINA, J.E. and CHIN, B. (1978) :

Cadmium modification of nuclear ultrastructure and RNA synthesis in Physarum polycephalum. Toxicol. Appl. Pharmacol. 43 : 449-460.

SNEDECOR, J. and COCHRAN, W. (1966) :

Statistical methods. The Iowa State Univ. Press Ames, Iowa, U.S.A.

SQUIBB, K.S. and COUSINS, R.J. (1973) :

Studies on the synthesis of cadmium binding protein using ^{109}Cd , ^{115}Cd and ^{14}C in liver and kidney. Fed. Proc. 32 : 924.

SQUIBB, K.S. and COUSINS, R.J. (1974) :

Control of cadmium binding protein synthesis in rat liver. Environ. Physiol. Biochem. 4 : 24-30.

STOLL, R.E.; WHITE, J.F. and MIYA, T.S. (1976) :

Effects of cadmium on nucleic acid and protein synthesis in rat liver. Toxicol. Appl. Pharmacol. 37 : 61-74.

✓ TATSUYAMA, K. ; EGAWA, H. ; YAMAMOTO, H. and SENMARU, H. (1975 a) :

Cadmium-resistant microorganisms in the soil polluted by the metals. Trans. Mycol. Soc. Jpn. 16(1) : 69-78.

✓ TATSUYAMA, K. ; EGAWA, H. ; YAMAMOTO, H. and SENMARU, H. (1975 b) :

Tolerance of cadmium-resistant microorganisms to the other metals. Trans. Mycol. Soc. Jpn. 16(1) : 79-85.

TATSUYAMA, K. ; EGAWA, H. and YAMAMOTO, Y. (1975 c) :

Tolerance of Penicillium lilacinum to cadmium and several other metals. Trans. Mycol. Soc. Jpn. 16(3):301-310.

THOM, C., and RAPER, K.B. (1945):

A manual of the Aspergilli. Williams and Wilkins Co. Baltimore, Md.

- TOHOYAMA, H. and MURAYAMA, T. (1977) :
Isolation and some characteristics of cadmium-resistant yeast. Agric. Biol. Chem. 41(8) : 1523-1524.
- TOLBA, M.K. ; SALAMA, A.M. and ALI, M.I. (1966) :
Effect of seed dressing with " Granosan " on the prevalence of fungi in the root zone of cotton plants. Nature, (Lond.) 211 : 1217-1218.
- TOLBA, M.K. and ALI, M.I. (1972) :
Studies on rhizosphere microflora of cotton plants in Egypt. Egypt. J. Bot., 15 : 23-43.
- ✓TURNER, R.G. (1969) :
Heavy metal tolerance in plants. In ecological aspects of the mineral nutrition of plants (ed. I.H. Rorison) PP. 399-410. Oxford, Edinburgh : Blackwell Scientific Publications.
- UCHIDA, Y. ; SAITO, A. ; KAZIWARA, H. and ENOMOTO, H. (1973):
Cadmium-resistant microorganisms. 1 : Isolation of cadmium-resistant bacteria and the uptake of cadmium by the organism. Saga Daigaku Nogaku Iho, 35 : 15-24.
- VOROB'EVA, I.A. ; GORYNOVA, S.V. and MAKSIMOV, V.N. (1979):
Intensity of photosynthesis of microalgae cultures under normal conditions and under the effect of cadmium and zinc; pH measurements. Gidrobiol. Zh. 15 : 64-70.
- WAKSMAN, S.A. (1917) :
Is there any fungus flora of the soil ? Soil Sci, 3 : 565-589.
- WARCUP, J.H. (1950) :
The soil plate method for isolation of fungi from soil. Nature, (Lond.), 166 : 117-118.
- WEBB, M. (1972) :
Binding of cadmium ions by rat liver and kidney. Biochem. Pharmacol. 21 : 2751-2765.
- WEBER, W.J. and POSELT, H.S. (1974) :
Equilibrium models and precipitation reactions for cadmium (11) - In A.J. Rubin, Ed., "Aqueous Environment Chemistry of Metals " Ann Arbor Science Publishers. Mich., 360 PP.

- WINGE, D.R. and RAJAGOPALAN, K.V. (1972) :
Purification and some properties of cadmium-
binding protein from rat liver. Arch. Biochem.
Biophys. 153 : 755.
- ZASUKHINA, G.D. ; SINELSCHIKOVA, T.A. ; LVOVA ,G.N. and
KIKOVA,Z.S. (1977):
Molecular genetic effects of cadmium chloride.
Mutat. Res. 45 : 169-74.
- ZIBILSKE, L.M. and WAGNER, G.H. (1982) :
Bacterial growth and fungal genera distribution
in soil amended with sewage sludge containing
cadmium, Chromium and copper. Soil. Sci. 134 :
364-70.

APPENDIX

Table a : Counts (per gm dry soil) of the common fungi in the rhizospheres of Glycine max (A) and Zea mays (B) after different treatments of the soil before cultivation with various doses of CdSO₄ or Cd(NO₃)₂.
22.7.1980

Fungal species	Control		Cd SO ₄ (ppm)						Occurra-						Cd (NO ₃) ₂ (ppm)						Occurra-					
			100		500		1000		2000		100		500		1000		2000		1000		2000		1000		2000	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<u>Aspergillus</u> spp.	380	300																								
<u>Aspergillus niger</u>	120	140																								
<u>A. terreus</u>	140	-	60	258	240	200																				
<u>A. clavatus</u>	20	20	40	43	40	60																				
<u>A. nidulans</u>	-	40	-	65	-	-																				
<u>A. flavus</u>	-	-	20	-	-	-																				
<u>A. fumigatus</u>	100	-	40	200	-	-																				
<u>A. carbonarius</u>	-	-	320	-	-	20																				
<u>A. sulphureus</u>	-	100	-	-	-	-																				
<u>A. luchuensis</u>	-	-	-	-	-	-																				
<u>Penicillium janthinillum</u>	-	-	-	-	-	-																				
<u>Fusarium oxysporum</u>	-	-	-	-	-	-																				
<u>Rhizopus oryzae</u>	100	100	100	108	100	80																				
<u>Chaetomium magnum</u>	-	-	-	-	-	-																				
<u>Paecilomyces divaricata</u>	20	-	-	-	-	-																				
<u>Curvularia tetramera</u>	-	-	20	-	20	40																				
<u>Cephalosporium curtips</u>	-	-	-	-	-	20																				
<u>Humicola brevis</u>	-	-	20	-	-	20																				
<u>Mycelia sterila hyuline</u>	20	-	60	-	-	20																				
Total	520	400	940	997	600	580																				
Number of genera	4	2	5	2	4	5																				
Number of species	7	5	10	6	6	8																				

Table b : Counts (per gm dry soil) of the common fungi in the rhizospheres of Glycine max (A) and Zea mays (B) after different treatments of the soil before cultivation with various doses of CdSO4 or Cd(NO3)2.

20.8.1980.

Fungal species	Control		Cd SO4 (ppm)						Occurra- nce.						Cd (NO3)2 ppm						Occurra- nce.	
			100		500		1000		2000		100		500		1000		2000					
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<u>Aspergillus</u> spp.	1494	844	589	730	439	822	361	737	374	294	1236	1045	926	689	246	400	236	488				
<u>Aspergillus niger</u>	580	340	168	84	229	232	170	63	112	42	360	192	166	354	80	120	-	148	H	H		
<u>A. terreus</u>	-	-	84	379	63	316	106	337	138	105	-	-	63	209	20	80	22	-	H	H		
<u>A. clavatus</u>	414	344	21	-	21	-	-	-	-	-	416	300	366	-	-	-	43	260	H	M		
<u>A. flavus</u>	260	80	21	-	42	-	-	-	21	42	320	-	58	42	20	-	-	60	H	M		
<u>A. nidulans</u>	-	-	21	21	-	-	-	21	-	21	-	-	-	-	-	20	-	-	H	M		
<u>A. humicola</u>	120	-	21	183	42	-	-	211	-	21	-	128	-	-	-	-	-	-	-	R		
<u>A. fumigatus</u>	40	80	42	-	-	190	85	63	62	42	-	21	42	63	80	120	106	20	H	H		
<u>A. funiculosus</u>	60	-	-	42	-	42	-	-	-	21	-	-	21	21	40	-	-	-	M	R		
<u>A. carbonarius</u>	-	-	211	21	42	42	-	21	41	-	140	21	210	-	-	60	-	-	M	M		
<u>A. luchuensis</u>	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	-	R	-		
<u>A. versicolor</u>	-	-	21	-	-	-	-	21	-	-	-	21	-	-	-	-	22	-	R	-		
<u>Penicillium lanthinillum</u>	-	-	-	-	-	-	-	21	-	-	-	21	-	-	-	60	-	-	R	-		
<u>P. rubrum</u>	-	-	-	42	-	42	-	42	-	190	-	-	-	-	-	160	-	-	M	M		
<u>Fusarium oxysporum</u>	-	-	63	-	42	-	-	63	82	-	-	43	-	-	-	-	-	-	-	-		
<u>Rhizopus oryzae</u>	80	100	42	84	42	-	21	42	21	21	100	43	63	21	80	80	22	100	R	H		
<u>Mucor silvaticus</u>	40	-	-	-	-	-	85	-	-	-	80	-	-	-	-	-	-	-	H	-		
<u>M. carticola</u>	40	-	-	-	63	-	-	-	-	-	-	63	84	21	60	-	-	100	R	-		
<u>M. variance</u>	-	-	-	63	-	42	-	-	-	-	-	-	-	-	-	20	-	-	M	-		
<u>M. sp.</u>	-	100	-	-	-	-	63	-	42	-	-	-	-	-	-	-	-	-	-	-		
<u>Chaetomium magnum</u>	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
<u>Paecilomyces divaricata</u>	140	220	-	106	21	-	128	-	21	-	-	21	169	-	-	80	-	220	R	-		
<u>Epicoccum nigrum</u>	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-	-		
<u>Cephalosporium curtis</u>	-	-	42	-	21	21	85	-	-	21	-	-	-	21	-	-	43	-	R	-		
<u>Trichoderma Koningii</u>	-	-	-	21	-	-	21	-	-	-	-	-	-	-	-	20	22	-	R	R		
<u>Phoma humicola</u>	-	-	-	21	-	21	21	63	-	21	-	21	-	-	-	-	106	-	R	M		
<u>Mycelia sterilia hyaline</u>	-	-	-	42	104	-	-	-	82	21	-	21	-	-	-	-	-	-	-	-		
Total	1814	1264	736	1109	732	948	722	1031	601	610	1416	1278	1242	836	380	820	429	908	3467	3842		
Number of genera	5	4	4	8	7	5	7	6	6	7	3	8	4	7	3	6	5	4				
Number of species	12	7	11	13	12	9	9	13	10	13	6	14	10	11	7	11	9	7				

Table c : Counts (per gm dry soil) of the common fungi in the rhizosphere of Glycine max (A) and Zea mays (B) after different treatments of the soil before cultivation with various doses of CdSO4 or Cd(NO3)2.

Fungal species	CdSO4(ppm)						Cd(NO3)2 (ppm)						Occurra- nce.		Occurra- nce.			
	100		500		1000		2000		100		500		1000		2000			
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		
<i>Aspergillus</i> spp.	1066	1327	422	333	821	622	259	512	333	332	599	553	532	466	700	1199	355	378
<i>Aspergillus niger</i>	111	429	222	133	311	222	141	156	111	89	H	H	282	44	133	50	489	67
<i>A. terreus</i>	22	184	-	67	178	67	-	111	89	111	M	M	47	22	22	-	44	67
<i>A. clavatus</i>	-	-	-	44	22	22	71	-	22	-	H	M	-	22	-	-	-	-
<i>A. flavus</i>	444	592	89	-	67	89	-	67	44	-	H	M	44	-	289	625	644	-
<i>A. nidulans</i>	-	-	-	67	-	22	-	-	-	44	-	H	-	-	-	-	22	M
<i>A. ustus</i>	156	102	67	-	111	111	47	156	67	44	H	H	267	200	44	25	44	156
<i>A. fumigatus</i>	22	-	44	-	22	89	-	-	-	22	M	M	-	-	-	-	-	89
<i>A. funiculosus</i>	-	-	-	-	-	-	-	-	-	-	-	-	200	-	-	-	-	-
<i>A. ochraceus</i>	22	-	22	22	22	-	-	-	-	22	R	M	-	-	-	-	-	M
<i>A. humicola</i>	178	-	-	22	22	-	-	-	-	-	R	-	-	-	-	-	-	R
<i>A. candidus</i>	22	-	-	-	22	-	-	-	-	-	R	-	22	-	-	-	-	M
<i>A. sydowi</i>	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>A. versicolor</i>	89	-	-	-	44	-	-	22	-	-	R	R	133	24	89	-	44	-
<i>Penicillium coryophyllum</i>	89	41	-	156	-	89	141	89	-	-	R	H	67	118	89	100	200	-
<i>P. lanthanillum</i>	44	-	-	-	22	-	-	-	-	-	R	-	-	-	44	-	-	M
<i>P. puberulum</i>	41	-	-	-	-	44	-	-	-	-	-	-	-	-	-	-	-	-
<i>Fusarium oxysporum</i>	44	-	44	-	-	-	-	-	-	-	R	-	-	-	-	-	200	-
<i>F. roseum</i>	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Rhizopus oryzae</i>	-	82	111	111	89	89	118	111	111	111	H	H	89	118	67	111	125	111
<i>Mucor jensenii</i>	-	-	-	-	22	-	-	-	-	-	-	-	44	-	-	22	-	M
<i>Cunninghamella echinulata</i>	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	R
<i>Paecilomyces divaricata</i>	-	-	-	67	-	31	-	-	-	67	-	H	-	-	-	-	-	-
<i>P. silvatica</i>	67	306	44	-	22	22	-	289	89	15	H	H	-	-	-	622	-	289
<i>Cephalosporium curtipis</i>	178	-	-	-	22	-	-	-	-	-	R	-	44	94	-	-	111	111
<i>Curvularia tetramera</i>	-	-	44	-	-	-	-	-	-	-	R	-	22	-	44	-	-	M
<i>C. geniculata</i>	-	-	-	-	-	-	-	-	-	-	-	R	-	24	-	-	-	111
<i>Alternaria fasciculata</i>	-	-	22	-	-	-	-	-	-	89	R	R	-	-	-	25	22	22
<i>Hilmarthosporium nodulosum</i>	-	-	22	-	22	-	-	-	-	67	R	R	-	-	-	-	-	H
<i>Trichoderma koningii</i>	-	-	89	67	-	-	-	-	-	44	R	M	-	-	-	-	-	-
<i>Humicola brevis</i>	41	-	-	-	-	-	24	-	-	22	R	R	-	-	-	-	22	-
<i>Phoma humicola</i>	22	-	-	-	-	-	-	-	-	-	-	-	44	-	-	-	22	-
<i>Myrothecium verrucaria</i>	-	245	200	200	-	106	-	533	-	-	R	H	44	-	100	50	-	-
<i>Candida albicans</i>	-	-	-	-	-	22	-	-	-	44	-	M	-	-	-	-	-	-
<i>Mycelia sterilia hyaline</i>	223	-	67	-	67	-	24	67	22	20	H	M	-	71	89	-	67	66
<i>Mycelia sterilia brown</i>	22	20	67	-	-	89	24	-	-	-	M	R	67	24	-	-	-	R
Total	1799	2103	1132	934	1087	1114	590	1601	555	811	3364	4460	1042	1002	1199	1110	900	1932
Number of genera	7	7	10	6	8	7	5	6	4	8	15	10	9	6	4	3	10	7
Number of species	18	12	14	10	17	15	8	10	8	15	15	10	16	8	6	6	16	10

Table d : Counts (Per gm dry soil) of the common fungi in the rhizospheres of Glycine max (A) and Zea mays (B) after 22.10.80 different treatments of the soil before cultivation with various doses of CdSO_4 or $\text{Cd}(\text{NO}_3)_2$

	Control			CdSO_4 (ppm)						Occurrence						$\text{Cd}(\text{NO}_3)_2$ (ppm)						Occurrence					
				100		500		1000		2000		100		500		100		500		100		500		100		500	
	A	B		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<u>Aspergillus spp.</u>	231	755		303	555	955	857	437	213	711	403					287	1145	450	400	600	966	288	500				
<u>Aspergillus niger</u>	21	22		47	111	67	204	163	118	178	156	H	H			22	125	75	225	100	200	-	200	H	H		
<u>A. terreus</u>	-	22		93	89	467	294	-	24	-	-	H	H			-	520	-	-	-	500	-	250	-	H		
<u>A. clavatus</u>	-	-		-	-	22	-	-	-	-	-	R	R			22	-	-	-	-	-	-	-	R	-		
<u>A. flavus</u>	-	444		47	178	-	118	253	71	111	125	H	H			22	50	-	150	320	44	-	25	M	H		
<u>A. nidulans</u>	63	-		23	22	89	-	-	-	22	-	H	R			89	125	-	-	40	100	22	-	H	M		
<u>A. ustus</u>	21	267		70	111	-	-	-	-	200	100	M	M			22	175	125	25	-	22	178	-	H	H		
<u>A. fumigatus</u>	21	-		-	22	244	194	-	-	-	-	R	R			22	25	-	-	40	-	44	-	H	R		
<u>A. funiculosus</u>	21	-		-	-	-	-	-	-	44	-	R	R			-	-	-	-	-	-	-	-	-	-		
<u>A. luchuensis</u>	21	-		-	22	44	47	21	-	-	22	M	H			44	125	-	-	100	100	44	25	H	H		
<u>A. ochraceovus</u>	-	-		-	-	22	-	-	-	67	-	M	-			-	-	-	-	-	-	-	-	-	-		
<u>A. sydowi</u>	21	-		-	-	-	-	-	-	22	-	R	-			44	-	-	-	-	-	-	-	-	R	-	
<u>A. versicolor</u>	42	-		23	-	-	-	-	-	67	-	M	-			-	-	250	-	-	-	-	-	-	R	-	
<u>Fusarium oxysporum</u>	147	-		186	-	-	-	-	-	44	-	M	-			444	-	-	-	-	-	-	-	187	-	M	
<u>Rhizopus oryzae</u>	-	111		93	111	89	118	105	118	22	111	H	H			-	125	125	100	100	111	67	125	H	H		
<u>Mucor sp.</u>	-	-		-	-	-	-	-	-	-	-	-	-			111	-	100	-	100	-	-	-	-	M		
<u>Cunninghamella echinulata</u>	-	-		-	-	-	-	-	-	22	-	R	-			-	-	25	-	-	-	67	-	M	-	-	
<u>Chaetomium magnum</u>	-	-		-	-	-	-	-	-	22	-	R	-			-	-	-	-	-	-	22	-	R	-	-	
<u>Paecilomyces divaricata</u>	-	-		-	-	-	145	-	115	-	-	-	M			-	-	-	-	-	-	-	25	-	R	-	
<u>P. silvatica</u>	-	689		-	671	-	635	100	24	178	337	M	H			111	130	-	297	100	362	-	625	M	H		
<u>Cephalosporium curties</u>	232	-		163	22	133	-	-	-	156	-	H	R			244	-	-	50	-	-	156	75	M	M		
<u>Verticillium candelabrum</u>	-	-		-	22	-	-	-	-	-	-	-	R			-	-	-	125	-	-	-	25	-	M		
<u>Curvularia tetramera</u>	-	-		23	22	200	24	-	-	22	22	H	H			44	75	25	100	100	100	22	25	H	H		
<u>C. geniculata</u>	-	-		-	-	44	24	100	-	-	-	M	M			-	25	-	75	-	-	22	-	R	M		
<u>Alternaria fasciculata</u>	-	22		-	-	-	-	-	-	22	-	R	-			22	-	-	25	-	-	44	-	M	R		
<u>Trichoderma koningii</u>	21	-		70	-	-	-	-	-	-	-	R	-			-	-	250	-	-	-	22	-	M	-		
<u>Humicola brevis</u>	21	22		-	22	-	-	24	156	44	M	M	M			111	-	75	-	20	-	22	-	H	-		
<u>Stachybotrys atra</u>	63	-		-	22	-	-	-	89	-	M	-	-			-	-	-	-	-	-	-	-	-	-		
<u>Myrothecium verrucaria</u>	253	-		116	22	117	71	147	71	156	160	H	H			-	50	-	105	-	-	-	-	-	M		
<u>Botryotrichum pulluliform</u>	105	-		-	-	44	-	-	-	44	50	M	-			-	-	-	-	-	-	44	60	R	R		
<u>Aureobasidium pullularia</u>	42	-		-	-	-	-	-	-	22	30	R	-			-	-	-	-	-	-	-	-	-	-		
<u>Arthrobotrys oligospora</u>	-	-		-	-	-	-	-	-	-	-	-	-			22	-	-	-	-	-	22	-	M	-		
<u>Mucella sterilis hyaline</u>	105	-		140	-	89	24	-	-	22	22	H	M			-	-	-	-	-	-	-	25	-	R		
<u>Mycelia sterilis brown</u>	21	-		-	-	67	-	-	-	-	-	R	-			22	-	25	25	20	22	-	25	H	H		
Total	1241	1599		1094	1425	1782	1918	889	565	1688	1201	5453	5109			1418	1550	1075	1302	1040	1561	985	1510	4518	5923		
Number of genera	10	5		8	7	9	6	5	5	15	9					10	5	8	9	7	5	12	8				
Number of species	18	8		13	13	17	12	7	8	22	13					17	12	10	12	11	10	16	13				

Table e : Counts (per gm dry soil) of the common fungi in the rhizospheres of Glycine max (A) and Zea mays (B) after different treatments of the soil before cultivation with various doses of CdSO4 or Cd(NO3)2.

20.11.1980

Fungal species	Cd S04(ppm)						Cd(NO3)2 (ppm)						Occur- ance.											
	Control			Occur- ance.			100			500				1000			2000							
	A	B		A	B		A	B		A	B			A	B		A	B						
<i>Aspergillus</i> spp.	320	860		422	394	576	511	160	510	300	139		555	345	422	261	400	444	319	147				
<i>Aspergillus niger</i>	60	280		222	111	111	289	140	133	20	89	H	H	44	94	67	141	80	156	-	67	H	H	H
<i>A. terreus</i>	20	80		67	144	311	89	-	67	-	-	M	M	67	80	22	24	-	22	89	20	H	H	H
<i>A. flavus</i>	80	160		-	-	22	44	-	178	100	50	M	-	-	71	167	24	200	44	44	20	H	H	H
<i>A. nidulans</i>	-	20		22	-	-	-	-	-	-	-	R	-	44	-	22	24	44	44	20	H	H	H	
<i>A. ustus</i>	80	100		111	67	44	89	-	44	20	-	H	H	178	100	100	24	80	156	31	20	H	H	H
<i>A. fumigatus</i>	-	-		-	22	-	-	-	-	-	-	R	-	-	-	24	40	-	-	-	-	M	-	-
<i>A. fumiculosus</i>	-	-		-	22	22	-	20	-	40	-	H	-	133	-	-	-	-	-	22	-	M	-	-
<i>A. humicola</i>	-	-		-	22	22	-	-	-	20	-	M	-	-	-	-	-	-	-	-	-	M	-	-
<i>A. carbonarius</i>	20	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	89	-	M	-	-
<i>A. ochraceous</i>	20	-		-	22	22	-	-	-	100	-	-	-	22	22	-	-	-	-	-	-	M	-	-
<i>A. parasiticus</i>	20	180		-	50	-	-	-	44	-	-	M	-	-	-	-	-	-	-	-	-	R	-	-
<i>A. lusitana</i>	40	-		-	-	-	-	-	44	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-
<i>A. sydowi</i>	20	-		-	-	22	-	-	-	-	-	R	-	67	22	-	-	-	-	-	-	M	-	-
<i>Penicillium puberulum</i>	-	-		-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	-	-
<i>Fusarium oxysporum</i>	240	-		356	-	-	-	356	-	-	-	-	-	22	56	40	20	-	-	44	-	H	-	-
<i>Rhizopus oryzae</i>	-	100		67	111	-	111	100	111	60	44	H	H	44	118	40	-	100	111	22	111	-	H	H
<i>Mucor silvaticus</i>	-	-		-	-	22	67	-	22	100	156	M	M	-	118	-	-	-	22	44	-	H	H	H
<i>Cunninghamella echinulata</i>	-	-		-	-	-	89	-	22	22	R	H	H	44	89	-	-	-	22	22	44	H	M	M
<i>Paecilomyces divaricata</i>	20	320		-	315	44	44	-	-	20	560	M	H	-	742	-	60	422	111	500	-	M	H	H
<i>P. silvatica</i>	20	240		-	100	155	-	-	308	-	-	-	-	300	-	-	-	22	-	-	-	R	R	R
<i>Cephalosporium curtipis</i>	100	-		200	178	156	-	-	-	44	M	M	M	267	50	189	47	44	233	22	67	H	H	H
<i>Curvularia tetramera</i>	40	-		89	22	44	-	-	22	20	-	H	M	-	-	-	-	22	67	-	-	R	R	R
<i>C. geniculata</i>	20	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Alternaria fasciculata</i>	-	-		22	-	22	-	-	-	60	-	H	-	-	-	-	-	-	-	22	-	-	-	-
<i>Alt. geophila</i>	-	-		-	-	-	-	-	-	22	-	-	-	-	71	-	-	-	-	-	-	-	-	-
<i>Cladosporium herbarum</i>	80	-		67	-	133	-	20	-	80	-	H	R	178	-	144	60	67	111	20	-	H	H	H
<i>Trichoderma koningii</i>	-	-		111	-	-	-	-	-	-	-	-	-	-	-	67	-	60	-	-	-	-	-	-
<i>Humicola brevis</i>	20	20		22	-	22	20	-	-	20	-	M	R	22	-	22	-	60	-	67	-	-	-	-
<i>Stemphylium verruculosum</i>	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Stachybotrys atra</i>	-	-		22	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-
<i>Myrothecium verrucaria</i>	140	-		133	108	133	111	-	144	60	-	H	H	133	24	122	47	140	67	56	25	H	H	H
<i>Botryotrichum pulliform</i>	40	-		44	-	-	-	-	-	-	-	-	-	22	-	-	-	-	111	-	-	-	-	-
<i>Avreobasidium pullularia</i>	60	-		-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	22	-	-	-	-	
<i>Candida albicans</i>	20	-		-	-	22	-	-	-	-	-	R	-	-	-	-	-	-	44	-	-	-	-	
<i>Mycelia sterilia hyaline</i>	240	-		22	-	137	-	-	67	-	67	M	M	111	-	222	24	-	-	133	15	H	M	M
<i>Mycelia sterilia brown</i>	-	20		44	22	22	-	-	-	80	-	H	R	-	47	22	24	60	44	44	15	H	H	H
<i>Mycelia sterilia oliva</i>	20	-		-	-	22	-	-	-	-	-	R	-	44	17	-	-	40	-	-	-	-	-	-
Total	1380	1560		1643	1250	1355	1108	636	1184	800	1054	4434	4596	1786	1515	1412	1397	940	1287	1541	943	5679	5142	5142
Number of genera	12	5		14	7	12	7	4	7	10	8			12	8	10	8	10	16	9				
Number of species	22	12		18	12	20	11	5	12	15	9			19	11	18	14	12	16	23	14			

ARABIC SUMMARY

خطط هذا البحث لدراسة تأثير معاملة التربة بتراكيز مختلفة من كبريتات الكادميوم او نترات الكادميوم على تواجد الفطريات النامية فى المنطقة المحيطة بجذور نباتات فول الصويا والذره فى جمهورية مصر العربية، وكذلك ايجاد توضيح ممكن للتغيرات الملاحظة فى الكائنات الدقيقة (الفطريات) فى حدود حساسية ومقاومة هذه الكائنات لايون الكادميوم وتتلخص النتائج كالاتى :-

- ١ - تم عزل وتعريف ٨١٦١ فطرة تمثل ٤٧ نوعا وتنتمى الى ٢٧ جنسا .
- ٢ - وجد ان أنواع الاسبيرجلاس تمثل المجموعة الفطرية المرتفعة درجة الوجود تحت الظروف التجريبية المختلفة وتمثل تقريبا نصف العدد الكلى لمعزولات الفطريات الجذر محيطيه . وكان اسبيرجلاس نيجر هو اعلى الانواع من حيث درجة الوجود والكثافة .
- ٣ - يمكن ترتيب المجموعات الفطرية التى تم عزلها ترتيبا تنازليا حسب درجة وجودها كالاتى : الفصيلة المونيليه (بحذف الاسبيرجلاس والينسيليوم) ، الفطريات الطحلبية ، الفصيلة الديماتية ، الفطريات العقيمه الغزل الفطرى ، الفطريات الزقيه ، الفيوزاريوم ثم البنسيليوم .
- ٤ - كان العدد الكلى لاجناس وأنواع الفطريات المعزولة من التربة المعاملة بملاح كبريتات الكادميوم او نترات الكادميوم اقل من العدد الكلى المعزول من التربة التى لم تعامل باى من املاح الكادميوم ولقد نوقشت التوضيحات الممكنة لتفسير هذه النتائج .
- ٥ - وجد ان طبيعة ونوع النباتات المستخدمة فى هذا البحث لها تأثير واضح على العدد الكلى للفطريات النامية فى المنطقة المحيطة بجذورها واتضح ان نباتات فول الصويا النامية تحت المعاملات التجريبية المختلفة يقلل احصائيا العدد الكلى للفطريات الجذر محيطية عن تلك التى تنمو حول جذور نباتات الذره .

- ٦ - تبين ان معاملة التربة بجرعات مختلفة من كبريتات الكادميوم أو نترات الكادميوم احدث نقصا احصائيا واضحا فى العدد الكلى للفطريات فى التربة . ولكن هذا التأثير كان نتيجة للنقص الواضح فى اعداد بعض الانواع والمجاميع الفطرية فحين ان بعض الانواع والمجاميع الاخرى اما لم تتأثر بايون الكادميوم او اظهرت زيادة واضحة فى اعدادها فى وجود الكادميوم ولقد نوقشت اهمية هذه الملاحظات فى دراسة تاثير ايونات المعادن الثقيلة على الكائنات الدقيقة .
- ٧ - ظهر ان مقاومة او حساسية الفطريات المختبره لايونات الكادميوم ليست وراثية ولكن نتيجة لعوامل اخرى متداخلة مثل طبيعة التربة ونوع الطمى فيها وكذلك محتوى المواد العضوية بها .
- ٨ - وجد ان افراز النيتروجين بواسطة الفطريات المختبره ليس ناتج من مقاومتهم لايون الكادميوم ولكن يعزى ذلك - بدرجة كبيرة - الى تاثير الكادميوم على نفاذية الخلايا لكل فطر على حدة .
- ٩ - ثبت ان الكادميوم يحد على تمثيل النيتروجين فى الاسبرجيس — لاس والفيوزاريوم ولكن معظم النيتروجين المتراكم كان فى صورة الامينات او فى صورة اخرى ذائبة . ولقد سبب تراكم كميات كافية من الكادميوم الغير عضوى فى بعض الفطريات المستخدمة اضطراب العمليات الايضية .
- ١٠ - شط الكادميوم احتواء الفوسفور الممتص فى مركبات غنية بالطاقة وصاحب ذلك عدم بلورة الاحماض الامينية الى بروتينات .
- ١١ - وضع ان الكادميوم يحفز افراز الاحماض العضوية فى المنافذ الغذائية التى تنمو عليها الفطريات الاربعة المختبرة .

جامعة القاهرة
كلية العلوم
قسم النبات

استجابة بعض فطريات التربة لمعاملات مختلفة من الكادميوم

رسالة مقدمة
لتحقيق درجة الماجستير في العلوم
(نبات - ميكروبيولوجي)

من
إيمان فتحى عبد الحميد شرف
(بكالوريوس العلوم - جامعة القاهرة ١٩٧٧)

فبراير ١٩٨٤