SECTION I

INTRODUCTION AND REVIEW OF LITERATURE
An important reserve for raising productivity and increasing the gross output of agricultural products is the elimination of losses of the harvest due to plant diseases, pests and weeds. The elimination of such significant losses is achieved by a variety of methods viz. agrotechnical, quarantine, physical, mechanical, biological and chemical plus integrated pest management and breeding plants for increasing host resistance. Much of the modern plant protection is however, accomplished by chemical substances like fungicides, antibiotics, pesticides and herbicides. Admittedly, all these methods are well intentioned in their purposeful planned actions against pests and diseases but majority of them have limitations besides merits. Exhaustive reviews on the subject are by Smith, 1962; Eckert and Sommer, 1967; Eckert, 1967, 1969, 1977; Ray Chaudhury and Vir, 1977; Green et al., 1977; Chandra and Khanna, 1984; Dekker and Georgopoulos, 1982; Gruzdyev, 1983.

**Physical Treatments**

1. **Low Temperature Storage**

   It is generally desirable to store fruits and vegetables at the lowest temperature (just above the freezing point) as low temperatures are considered to prevent physiological deterioration, slow down fruit ripening and are also supposed to smother the growth of
the pathogen. Thus apples, peaches, plums and grapes can be stored near 0°C (Wright et al., 1954). Although growth of many fungi is completely stopped at this temperature, some post harvest pathogens continue to prosper (Gunderson, 1961). For example, apples and pears stored at such temperatures are reported to be attacked by *Penicillium expansum*, *Cladosporium herbarum* and *Botrytis cinerea*. Some fungi even grow at temperatures as low as -20°C (Hawker et al., 1960). Furthermore, fruits like apples, bananas, citrus, mangoes, pineapples, avocados, as well as many vegetables sustain chilling injuries if held below 5 or 10°C and also become prone to infections by fungi other than those for which the treatment was administered. For instance, tomatoes previously stored at 5-10°C develop infections of *Alternaria tenuis* (McColloch and Worthington, 1952), *Geotrichum candidum* (Butler, 1960), *Erwinia carotovora* or *Aerobacter cloacae* (Segall, 1967).

11. Heat

Disease development could presumably be checked by storage at temperatures above the maximum required for the growth of the pathogen. Tindale et al. (1958) have reported that in Australia peach fruits are maintained at 35°C for sometime prior to canning, so as to avoid brown rot caused by *Monilinia fructicola*. But this sort of treatment is often associated with some severe problems
such as, fruits become shrivelled due to excessive moisture loss and flavour is adversely affected and the hosts become susceptible to infections by *Aspergillus* and certain species of *Rhizopus* which very much enjoy this range of temperature.

More promising have been brief exposures of temperatures high enough to inactivate lesions, for example, hot water at 60°C for 1.5 minutes proved lethal to not so deep infections of *Phytophthora* sp. on mature green tomatoes (Rosenbaum, 1920), though sensitizing the host to *Alternaria* rot (Barkai Golan, 1973). Similarly 46–48°C hot water dip for 2–4 minutes could inactivate brown rot lesions caused by *Phytophthora* sp. (Fawcett, 1922) although this made lemons more homely for *Penicillia* and other fungi (Klotz and Dewolfe, 1961; Harding and Savage, 1964). Hot water immersions or steam baths have likewise been commercially employed to control incipient fungal infections of several kinds of papaya, mangoes, peaches, strawberries, apples, oranges etc. (Pennock and Maldonado, 1962; Smoot and Segall, 1963; Smith, 1962; Smith and Basset, 1964; Smoot and Melvin, 1964; Burchill, 1964; Couey and Follstad, 1966). But heat pasteurization has proved ineffective in several other cases.

iii. **Radiation**

Radiation therapy was developed to treat the deep seated infections because of the penetrative power of
ionizing radiations. Among the several types of radiations used in controlling post harvest fruit and vegetable diseases, gamma have been found most successful. Unfortunately, this has also met with serious shortcomings. The fault of the therapy is that the radiation dose sufficient to kill the lesion is generally associated with deleterious effects on the host. For example, control of *Penicillium* and other rots of citrus fruits by X-rays results in increased host susceptibility towards *Alternaria citri* (Beraha et al., 1959). Storage rot fungi of apples, pears, peaches and lemons are inhibited by X-rays (Beraha, 1964; Terui et al., 1965) but adverse physiological effects on the host limit its use (Maxie et al., 1971).

**CHEMICAL TREATMENTS**

i. **Fungicides**

One of the earliest treatments employed to control the post harvest decay of citrus fruits were alkaline solutions of sodium tetraborate (Borax) and sodium carbonate (Barger, 1928; Barger and Hawkins, 1925; Fulton and Bowman, 1924). But their application has now been stopped since disposal of the water containing the phytotoxic borax residue from the fruit surface poses a pollution problem. Similarly sodium carbonate treatment may predispose yellow lemons to decay (Harding and Savage, 1964).
Bordeaux mixture as a major copper fungicide has been in use for controlling a wide variety of fungal diseases. But in view of its phytotoxicity on certain plants, particularly fruits, such as, apples and pears etc. and its tendency of delaying ripening, its use was discouraged and attempts were made to find some suitable alternative. Lime was added to minimize its phytotoxicity but lime sometimes itself proved injurious (Horsfall et al., 1938). Copper toxicity is also reported in some of the high yielding varieties of paddy, maize and other crops. An interesting relationship between copper sprays and increased frost damage has been reported by Wilson (1947) in case of potatoes and tomatoes. The effect of frost damage in these crops when sprayed with various copper fungicides was more severe as compared to those plants which were sprayed with non-copper fungicides. Besides, copper sulphate has also been reported to be mutagenic (Vasilos and Dmitricenko, 1972).

Likewise, mercurial compounds have also been known for their fungicidal and bactericidal properties for many years but soon they were replaced by organic mercurial compounds owing to their extremely toxic nature. Ethyl, phenyl and methoxy methyl mercury compounds were then in use, mainly as seed disinfectants but they caused seed
injury in several cases (Crosier and Midyette, 1955; Hsi, 1956; Koehler and Bever, 1954; Purdy, 1956). Such injured seeds germinate into abnormal cereal seedlings, with some of the cells displaying anomalous cytological behaviour (Sass, 1937). Ahmed and Grant (1972) have also found mercurial fungicide panagon-15 to induce severe chromosomal abnormalities similar to colchicine on the root meristems of *Tradescantia* and *Vicia faba*. Phenyl mercuric acetate has also been found to induce mitotic inhibition and polyploidy (Bielecki, 1974). Coresan and hexasan the common fungitoxic mercurial compounds have been reported to produce strong radiomimetic effects on seedlings of *Hordeum vulgare* and root cells of *Vicia faba* (Zutshi and Kaul, 1975). Richmond (1981) has discussed the effects of organomercury compounds in relation to phytotoxicity and cytological abnormalities induced by them. For these reasons, Food and Drug Administration of U.S.A. has disapproved the use of all such mercurial fungicides.

Sulphur in different forms is widespread in use against powdery mildews on a variety of crops, certain rusts, leaf blights and fruit rots and also as an insecticide. However, certain harmful effects restrict its frequent usage. At least its employment in hotter climate is to be avoided, since in hotter climates severe burning is sometimes caused such as on cucurbits, when they are treated with sulphur. Apples treated with sulphur
in semiarid areas may develop "Sun seals" on the sun exposed sides. Besides, sulphur is also reported to inhibit pollen germination (McDaniels and Furr, 1930) and reduce photosynthesis considerably (Kozlowski and Keller, 1968).

$\text{SO}_2$ fumigation has been found promising with regard to the control of Botrytis decay of table grapes (Nelson and Baker, 1963) and to a lesser extent against the Cladosporium or Alternaria decay of raspberries (Cappellini et al., 1961) but its phytotoxicity has restricted its usefulness in controlling plant diseases. The concentrations required to eradicate the infection have been found to be intolerable by the hosts resulting in severe injuries (Worthington and Smith, 1965).

Biphenyl vapours have been shown to be strongly fungitoxic to a large number of plant pathogenic fungi such as, *Penicillium digitatum*, *P. italicum*, *Diplodia natalensis*, *Phomopsis citri*, *Botrytis cinerea*, *Rhizopus stolonifer*, *Fusarium* sp. (Ramsey et al., 1944; Heiberg and Ramsey, 1946; Mckee and Boyd, 1962; Tomkina, 1936). This property of biphenyl has been used on commercial scale in controlling decays of lemons, oranges, peaches, potatoes and grapes caused by above mentioned pathogens. But the action of this compound has got certain limitations. Firstly, it is purely fungistatic. Then the taste of the treated commodities is adversely affected. In certain
cases fruits sustain injuries (Tomkins, 1936). Moreover, repeated exposure to the biphenyl vapours has also resulted in the development of resistance in *Penicillium* sp. and *Diplodia natalensis* (Farkas and Aman, 1940; Harding, 1959) and lemons developed susceptibility towards *Alternaria citri* infections (Harvey and Atrops, 1953).

Halogenated hydrocarbons and their derivatives have been extensively tried to check post harvest decays in several fruits but they have been found to be injurious to hosts at concentrations required for control of decay (Vandemark and Sharvelle, 1952). Volatile O-phenyl phenol and its related compounds in the form of paper wraps were also considered effective in reducing decay in several varieties of fruits but unfortunately they caused severe scalding in majority of cases (Tomkins, 1936). Not only this, treatment of lemons with this substance has caused the selection of resistant population of *Penicillium digitatum* and the fungicide is now no more effective against this green mold (Eckert, 1969; Georgopoulos, 1969). Ammonia and several of the amines were also reported to perform effectively against citrus fruit decays but later on their commercial application was abandoned in light of their phytotoxic properties. These fumigants may be lethal at high concentrations to pathogen propagules but at concentrations tolerated by the host they are fungistatic (Eckert and Kolbezen, 1963).
Captan (N-trichloromethyl-thio-tetrahydrophthalimide) and Folpet (N-trichloromethylthiophthalimide) are distinguished by their high fungicidal action. They are effective against downy mildews. Folpet also inhibits the development of powdery mildew fungi. They have been evaluated both as a preharvest spray and a post harvest dip to control decays of several fruits including strawberries, peaches, cherries, apples, pears, figs, grapes, potatoes, tomatoes etc., during storage and marketing. But then there are certain problems associated with their application. The main decomposition products of Captan and Folpet on plants (Phthalimide and tetrahydrophthalimide) have a noticeable teratogenic action. Captan is also a potent mutagen of bacterial cells (Bridges, 1975). Captan has been reported to induce chromosomal aberrations in human and rat kangaroo cells (Legator et al., 1967). The possible mutagenic effects of captan have been reviewed in great detail by Bridges (1975). Folpet and difolatan also induce comparable effects (Bridges, 1975). Apart from this, regular use of captan against apple scab is attended by a growth of powdery mildew in the relevant areas. Captan is reported to be very toxic to fish and inhibits the development of many soil microorganisms.

Zineb (lonacol or dithane Z-78; zinc ethylene bisdithiocarbamate) is mainly used as foliar sprays against diseases, such as early and late blight of potatoes and
tomatoes, blast of rice, leaf blight of rice, ripe rot of chillies and downy mildew of maize. This protective fungicide also prevents the development of several other diseases, like grapevine mildew, blue mold of sugar beets and tobacco, and scab of apples and pears. But this compound has also been reported as slightly blastomutagenic, mutagenic and embryotoxic (Gruzdyev, 1983). Thiodicarbamates decompose rapidly in water into ethylene thiourea which is mutagenic to bacteria and induce tumours in mice. Thiodicarbamates can also react with nitricious in the stomach to form the known carcinogen dimethyl nitrosamine. The toxicological properties of the dithiocarbamates are reviewed by Fishbein (1976). Some dithiocarbamates are also reported to cause deformities in the embryos of clawed toad, *Xenopus laevis*, (Bancroft and Prahlad, 1973), inhibit melanin synthesis and induce structural abnormalities in the thyroid of rat. Besides, it may also cause allergic affections of the skin and asthma. Carbon disulphide, hydrogen sulphide and other products of Zineb decomposition may accumulate in the air surrounding the treated area in concentrations dangerous to human health (Gruzdyev, 1983). Dinocap (Karathane, 2,4-dinitro-6 octyl phenyl crotonate), the nitro derivative of phenol is a contact fungicide with protective and curative action. It prevents the growth of powdery mildew fungi on a large number of fruits. It protects plants from infection by scab, and has an
acaricidal action. Roses and chrysanthemum during their vegetation period are also sprayed with this compound. But dinocap is reported to be highly toxic to humans. Morestan or Quinomethionate is a contact substance with protective and eradicating action. It is effective in controlling powdery mildew and also possesses acaricidal properties. It is recommended only for spraying seedlings and cuttings in nurseries of apple and pear trees and grapevines during the vegetative period. Dexon (p-dimethyl amino benzene diozasodium sulphonate) is used against soil borne phycomycetous fungi causing root rot and damping off diseases of plants. It has a curative effect on avocado seedlings affected with Phytophthora cinnamomi when applied in the root region.

Zineb, dinocap, morestan and dexon as mentioned above are all very good fungicides but their integrity can be doubted as they are reported by Zutai and Kaul (1975) to produce strong radiomimetic effects on seedlings of Hordeum vulgare and root cells of Vicia faba. Chromatid breaks, isolocus breaks, chromatid exchanges and bridges were the most commonly observed effects.

Thiram (TMTD, tetramethyl thiuram disulphide) is a leading seed treatment of wheat, gram, rice, peas, mustard, linseed, mustard, sorghum, onion and potato tubers. PGNB (Pentachloronitrobenzene) is used for dressing the seeds
of wheat for common bunt and rye for flag smut and potato seed tubers for late blight and scab. Chloranil (Tetrachloro-p-benzoquinone) is yet another seed dresser and is also employed as a soil drench. But these seed dressers have been reported to cause amitotic, mitotic and meiotic abnormalities of varied kinds in the root tips of Allium sativum which characterize them as potentially mutagenic (Oswal, 1982).

Major advances in plant disease control came from systemic fungicides which first appeared in 1964. They have been ably dealt with by Murrah (1972). Benomyl marketed as Benlate (methyl-10 (butyl carbamoyl) -2 benzimidazole carbamate) has been found effective against a wide range of pathogens. It is effective against Cercospora leaf spot of sugar beet, rice blast, apple scab, powdery mildew on cucurbits, cereals and legumes and a lot many diseases. In an aqueous medium, benomyl decomposes into methyl benzimidazol 2-yl carbamate (MBC or carbendazim), butylamine and CO₂. Carbendazim has been shown to be the principal fungitoxin of benomyl.

Thiabendazole (TBZ), a derivative of benomyl similarly possesses a broad spectrum of antifungal activity. TBZ has been demonstrated to substantially reduce Penicillium decays of oranges (Crivelli, 1966; Brown et al., 1967) and infections of Penicillium expansum on apples. Richmond (1981) has described benomyl protecting plants from the
damage of ozone polluted atmosphere and to possess acaricidal and nematicidal properties. Another derivative of benomyl is Bavistin which is effective against ascomycetes and fungi imperfectii which are considered to be hard to control otherwise.

But benomyl application is associated with several untoward effects. The toxicological and genetic effects of benzimidazole fungicides have been reviewed by Seiler, 1975. Benomyl and carbendazim induce mitotic abnormalities in roots of onion and in cultures of mammalian cells. Benomyl is reported to induce point mutations in Fusarium oxysporum and in Bacteria but not in higher organisms where this effect is concealed by its stronger action on mitosis (Seiler, 1975). The benzimidazole fungicides, except those with trifluoromethyl groups, induce haploid segregants in diploid strains of Aspergillus nidulans (Hastie, 1970) by mitotic disjunction. Benomyl, TBZ or NBC applications have given rise to a very significant and alarming problem. Several fungal pathogens which were highly sensitive towards these substances earlier have developed resistance towards them. These fungi are, Penicillium italicum and P. digitatum from citrus fruits (Harding, 1972). P. bervicompactum and P. corymbiferum from cyclamen bulbs (Bollen, 1971). Sphaerotheca fuliginea from cucumber (Schroeder and Provvidenti, 1969; Bent et al., 1971).
Cytotoxic, mutagenic and toxicologic effects of Benomyl and related compounds have been dealt with in great details by Richmond (1981). Benomyl may belong to a new class of base analogue mutagens which are incorporated into DNA and provoke mutations by misrepair of gaps in newly synthesized DNA. Benomyl and TBZ incorporated into soil depress the growth of seedlings of American elm, marigold, buckthorn and sycamore. Benomyl is also phytotoxic to seedlings of cabbage, brussels, sprouts and cauliflower. It has also been reported to inhibit host phenylalanine ammonia lase enzyme which may be involved in natural defense mechanisms. *Vitavax* (DCMO or carboxin) 2, 3-dihydro-5-carboxanilido-6-methyl 1, 4-Oxathiin is effective against all kinds of bunt and smut and also against rust fungi. *Plantavax*, the sulphone derivative of *vitavax* is effective against rusts and is also effective as seed and soil treatment. But these oxathiins are also reported to cause mitotic and meiotic chromosomal abnormalities (Oswal, 1982).

11. **Pesticides**

Presently, pesticides the chemical means of plant protection, are being extensively employed to control most pests on all agricultural crops and also to treat granaries, storage bins, green houses etc. and this has substantially increased and saved agricultural and horticultural yield.
But they too have been shown to have undesirable side effects so much so that masses have grown apprehensive about their production and use.

The very role of pesticides in increasing the agricultural production is increasingly becoming doubtful. The problem of resistance among the pests is assuming alarming proportions and in many instances, the pesticides have achieved just the opposite of what they were supposed to achieve. They have created more and more complex pest problems than ever before. In the beginning, the application of high yielding varieties with pesticides does raise the production. But soon, unforeseen pest epidemics and food crises may appear.

Increasing resistance among the pests to chemical pesticides is the failure of the pesticide technology. With the heavy use of toxic chemicals, more and more strains of pests are developing resistance and new pests are coming up. If higher doses of pesticides are used, eventually the pest may become almost immune so that even increased doses are no longer effective. Often cross-resistance occurs where more than one species of pests can develop resistance simultaneously and multiple resistance occurs where resistance to one substance is accompanied by resistance to several others. As the sequence proceeds, the number of options is rapidly reduced until, in extreme cases, we are faced with pest populations highly resistant
to virtually all available pesticides.

The problem is aggravated by another factor. There are always some natural enemies of pests in the form of parasites and predators who keep the pest population in control. But a chemical pesticide may kill not only the target pest but also the natural enemies of it and other pests. Thus, freed from some of the natural controls, the population of the original pest may explode to unprecedented numbers. In this way, the pesticide use may achieve just the opposite. Furthermore, the pesticide sometimes may kill the natural enemies of another relatively innocuous species, which released from parasite/predator pressure may multiply in number and grow into a new pest.

Almost the entire range of pesticides produced and used in India is dangerous to human life. DDT, BHC, Endrine, Eldrine, Heptachlor, Kenone, 2, 4, 5-T;2, 4-D, chlordane, sodium cyanide, and lindane etc. have all been declared dangerous by the World Health Organization but they are still being imported and widely used in our country with impunity.

The manufacturing of pesticides involves the use of highly toxic chemicals. The wastes dumped in the neighbourhood, and the smoke released in the atmosphere are also very poisonous.
In 1972 WHO's expert committee on insecticides estimated that there were about 5 lakh cases of pesticide poisoning annually all over the world. Of these at least 5000 died. Besides, a large number of others suffer from cancer, birth defects and genetic mutations resulting from the use of pesticides. Bhopal accident is an example that brought into light the enormous poisonous potentialities of the pesticides. These pesticide poisons do enter the ecosystem and become threat to human life in more than one ways.

There is sufficient amount of literature to indicate that several of the pesticides are potentially mutagenic or teratogenic. For example hexachlorocyclohexane (HCCH), chlorodane, toxaphene, aldrine, dieldrin, isodrin, endrin and DDT have been reported to cause a wide variety of cytological and chromosomal effects on the root tip of Allium cepa and Fragaria vesca (Scholes, 1953, 1955a, 1955b). Wuu and Grant (1966, 1967a, 1967b) investigating the effects of 15 pesticides, including aldrin, phospha-
midon, sevin, ENT-50612 and botran, have reported these chemicals bringing about deviations from normal chromosomal behaviour at meiosis and mitosis. Menazon, metobromuron and tetrachloroisopthalonitrile induce chromosomal abnormalities on Hordeum and Tradescantia. Kilgore and Ming-Yu-Li (1973) reviewing the carcinogenicity of pesticides have made a reference to US Commission on Pesticides and their relationships to environmental health
which examine data over 100 pesticidal chemicals and inferred that at least some were tumorigenic and few could be carcinogenic. Singh et al. (1975) have noted meiotic anomalies induced by such commonly used insecticides like endrine, cythion, ambithione, dimukron, cytrophin, Thimet, AC-92100, furadon and disyston. Amer et al. (1971); Amer and Farah (1979) have also observed sevin and leptophos inducing disturbances in mitotic and meiotic behaviours of root cell nuclei in *Vicia faba*.

iii. **Herbicides**

Herbicides are chemicals employed to inhibit or kill weeds without harming the crop plants. Several groups of such substances are in common use now a days. For example, derivatives of phenoxyacetin acid, i.e., 2, 4-D and MCPA are employed on commercial scale to eradicate numerous dicot weeds from the crops of wheat, rye, barley, millet, sorghum, rice, oat, corn etc. Derivatives of 1,3, 5-triazine-azazine and simazine are used to kill many di and monocotyledonous weeds mainly on cornfields. Similarly, propanil is required to destroy millet like dicots from paddy fields. Carbamate compound CIPC kills weeds in clover and onion plantations. Trifluralin, the aromatic amine is a very good weedicide for cotton, casterbean, soyabean and sunflower fields. Dalapon is a selective herbicide employed in damaging graminaceous weeds from the orchards of berry and grape wines. These are but
only a few examples to show that how important are herbicides in modern agricultural and horticultural practices. But they should be used with a plenty of caution, because employment of some of these herbicides have caused the problem of resistance in certain weeds. For example, weeds like common spurrey, hemp nettle, cleavers, black night shade which were quite sensitive to these herbicides and they are now being controlled by other herbicidal compounds like DNOC, Actril AS and Actril M. Moreover, not a single herbicide is free from toxicity on warm blooded animals and human being. Residues of DNOC and 2,4-D and several other herbicides cannot be tolerated in food products. Some of these chemicals are also reported to induce cytological and chromosomal abnormalities of various kinds in the treated plants. Herichova (1971) has reported that iso-propyl-N-phenyl carbamate alters chromosomal structure and prevents cytokinesis in the meristematic cells of Hordeum vulgare. Accumulation of C-metaphase, spirallized chromosomes, polyploid nuclei, micronuclei and binucleate cells are the varied manifestations of the carbamate treatment. Fragmentation of endoplasmic reticulum and golgi apparatus as brought about by CIPC were also reported by him.

CIPC is also reported to inhibit mitosis and mitotic spindle and causes stickiness and pycnosis of chromosomes in Allium cepa and Hordeum vulgare (Guenther and Nasta, 1972).
Bartels and Hilton (1973) have compared the effects of trifluralin, oryzalin, pronamide, prophpam and colchicine on microtubules and have noted disruption or prevention of the assembly of microtubules. Hakeem and Shehab (1974) investigated the effects of dalapan, graminoxone and 2, 4-D-amine on *Vicia faba* cells and reported mitotic and meiotic abnormalities like stickiness, bridges, laggards, fragments and polyploidy.

Cotton roots display cytological aberrations under the influence of trifluralin in a way typical of colchicine (Hess and Bayer, 1974). Cytogenetic effects of 2, 4-D include chromosomal bridges, fragments, laggards and chromosomal contractions (Mohandas and Grant, 1972; Singh and Harvey, 1975).

iv. Antibiotics

The use of antibiotics in plant disease control is comparatively recent. A considerable number of them including tetracyclines, griseofulvin, cycloheximide, aureofungin, nystatin, talsutin, penicillin, pantoene, streptomycin etc. are being employed to control several phytopathogenic diseases (Brian, 1949; Zaumeyer and Doolittle, 1956; Zaumeyer and Wester, 1956; Dimarko and Davis, 1957; Ford et al., 1958; Dimond, 1959; Ananthanarayanan and Seshadri, 1965; Dharamvir, 1967; Eckert, 1967; Gottleib and Shaw, 1970; Sharma and Waheb,
1970; Thakur and Chenulu, 1970; Shankhpal and Hatwalne, 1975). But so far as fungal diseases are concerned, they have not been of much success. Economic, medical and cytological considerations restrict their widespread use.

Benbadis et al. (1971) have reported that chloramphenicol, cycloheximide and tubulosin cause a prolongation of G2 phase of cell cycle in the root meristems of Allium sativum. Bempong (1971, 1972a, 1972b and 1973) found daunomycin and mitomycin C producing abnormalities in mitotic and meiotic chromosomes. Shah (1975) observed that chloramphenicol and puromycin affected protein synthesis, DNA synthesis and histone-DNA interactions; actinomycin inhibited intracellular RNA while mitomycin C inhibited cell division. Griseofulvin is known to bring about inhibition of mitosis in higher plants, animals and fungi through the disruption of mitotic spindle (Richmond and Phillips, 1975). This antibiotic also inhibits hyphal tip formation (Gruzdyev, 1983).

From numerous reports, iatrogenic action of antibiotics is beyond doubt. Penicillin could pose abortifacient action causing premature birth or foetal death. Streptomycin is reported to provoke deafness, tetracycline hampers the normal development of bones and caused congenital limp abnormalities (Kabir, 1979).
DISEASE RESISTANT VARIETIES

Hot humid climatic conditions of India are quite favourable for the development of a variety of organisms harmful to plants. Cultivation of disease resistant varieties is therefore supposed to be most valid method of disease control. But the experience is just the opposite in many cases. As we breed a particular variety for disease resistance, the disease causing organism also breeds and multiplies, thus giving rise to new races and biotypes to which the variety in question has no resistance under such circumstances. There is great fear of development of an epidemic of these vagaries. The point can be illustrated by the example of wheat. A large number of wheat varieties, claimed to be disease resistant, have been developed after years of experimentation under All India Coordinated Wheat Improvement Project (ICAR) but majority of them have been found to loose resistance against a large number of organisms. In the last decade or so a number of varieties possessing reasonable field resistance have been released but with the exception of Kalayansona (or s.227, HD 1593) and sonalika (or s.308, PR 21, HD 1553) none of the other varieties could make an impact in wheat cultivation. Kalyansona variety at the time of its release was resistant to black and yellow rusts under field conditions and was practically immune to loose smut of wheat, resistant to hill bunts and tolerant to blights. However, the emergence
of new biotypes of yellow rust (i.e., 14 A, 20 A and 38 A) rendered this variety highly susceptible to yellow rust. It was also extremely vulnerable to brown rust. SonaBlika, once the most promising variety of wheat has also become quite susceptible gradually. Safed Lerma variety was recommended for south Indian hills because of its resistance to black rust races but just in a period of 2 years, it became susceptible and later Choti Lerma was introduced in the area, but it was soon attacked by new races of yellow rusts. Similarly, Karnal bunt of wheat caused by *Neovossia indica* was considered till recently a disease of minor importance but it assumed an epidemic proportion in northern India in 1974-'76, and is now supposed to be a major wheat scourge when all the 'aestivum' wheat varieties have become susceptible to this deadly disease.

**Drawbacks of existing methods and alternative strategies**

It is obvious from the foregoing that majority of the methods currently employed for the control of phytopathogenic diseases and for the protection of plants in general are obsessed with this or that kind of problem. Their credibility is in jeopardy. Some of them are cost prohibitive while others pose a danger of environmental pollution. A number of them specially the systemics leave harmful residues in the plant parts and thus cause insidious effects on human health in long term. The
influence upon the environment of the inexpert handling of some of the chemicals can be devastating. Still others have been reported to show mutagenic, antimitotic, teratogenic or carcinogenic effects in a number of biological systems. Moreover, indiscriminate use of these substances has led to the development of resistant strains and biotypes of several pests and pathogens which have practically become insensitive to plant protection chemicals. Thus, a crisis is causing a fundamental shakeup among plant protectionists. Do we need plant protection, and if so do we need chemical protection? Can it be replaced by safer procedures?

Reports on increasing failures of chemical plant protection, on the unwanted side effects of chemicals, on the unsolved problems of toxicity and resistance and their escalating costs due to the exploitative means adopted by the manufacturers - this all has compelled plant scientists to search for alternative methods of plant protection.

Prof. David Pimentel (1978) is of the firm view that if use of such chemicals is stopped, there will be no serious food shortage in USA. It is a myth that the food production should depend crucially on the use of chemicals.

Eckert (1967) is also of the view that attempts to search new fungicides suitable for post harvest treatment should be made instead of modifying the existing ones.
Fred Klingauf (1982) in his article, "Do developing countries require plant protection?" has stressed the need to replace the existing methods of chemical protection by new chemicals that are non-toxic and ecologically justifiable. He further suggests that natural resources from native plants should be exploited for such purposes. Committee of International Society for Plant Pathology on Chemical Control (Anonymous, 1980b) has also emphasized on the search for new controlling agents.

**Homoeopathic drugs - a new promise**

Guided by this purposiveness, plant scientists started looking for such "genuine" substances. And it was only natural that their attention was drawn to homoeopathic drugs, which are in use since long for the treatment of human ailments. Homoeopathic drugs, as we all know, are natural substances employed in ultra high dilutions and in potentized form. The process of potentization is unique only to homoeopathy and has never been used anywhere so far. It confers upon the unmedicinal substance with such a great and hitherto unknown, undreamed of, change by the development and liberation of the dynamic powers of the medicines that deep seated therapeutic virtues are unfolded to an almost boundless extent as to excite our astonishment. Besides, they are extremely cheap, easy to
handle, safe in environment and are supposedly harmless otherwise. These qualities distinguish them as substances qualitatively different from the mainstream chemicals. That is why homoeopathy is experiencing a resurgence in all countries not because of its therapeutic efficacy but also because of the absence of any problem with "side effects", "adverse reactions" and iatrogenic diseases which increasingly plague our society. Attempts made in recent past to exploit them in the field of plant protection afford a few tantalizing clues. A review of literature given below might be a pointer toward the prospects of applying homoeo drugs in the field of plant protection.

The innovative idea that homoeopathic drugs could be put at the disposal of plants, came to limelight when Idris for the first time in 1967 presented his findings at the International homoeo congress held at New Delhi.

Invigorated by the works of Idris, a few plant scientists were prompted to try these drugs in the field of plant protection and their findings even at this early stage, made it obvious that these drugs could be beneficial in more than one ways.

**Homoeo drugs as Antiviral agents**

Khurana (1968) tried three homoeo drugs, viz., Apis M. 30, Belladona 30 and Euphrasia 30 to ascertain their
efficacy on the infectivity of three papaya viruses, papaya distortion ring spot (PDRV), Ringspot (PKSV) and Mild mosaic (PMMV). All the drugs had inhibitory effect but PDRV, the severe of the viruses was more sensitive. When inocula of these viruses were mixed with another three drugs namely Bryonia A.30, Sulphur 30 and Thuja 0.30, upto 80% inhibition was observed. Khurana (1971) further reported that papaya and cucumber plants pretreated with sulphur 30 and Thuja 30 afforded 80% protection against PDRV and cucumber mosaic virus (CMV) respectively.

Verma et al. (1969) screened 12 homoeo and pharmacopoeial drugs against tobacco mosaic virus (TMV) infection in vitro. They recorded that the treatment of TMV infected tobacco leaf discs with 7x potencies of Chimaphilla, Lachesis, Cedron, Chenopodium, Variolinum and Carboveg in descending order of efficacy, resulted in a higher degree of reduction in the viral content. Moreover, Chimaphilla and Lachesis (31 and 201 potencies) but not the other drugs, could reduce the virus content by 50% in 10 days old infected tissues. Among pharmacopoeial drugs, Ipecac and Jalapa inhibited TMV infectivity on Nicotiana glutinosa but not on N. tabacum. Furthermore, Artemisia, Digitalis, Alstonia and Viburnum could check TMV infection by almost 50% and reduced virus multiplication by 75-80%.

Abidi et al. (1977) tested 5 homoeo drugs (4 of which were common with that reported by Verma et al., 1969)
against PDV. They confirmed that Chimaphilla and Lachesis were good preventives against virus infection in papaya seedlings pretreated with them. Rhustox, afforded only 30% inhibition of PDV when applied postinfectionally. All the 5 drugs induced antiviral effects and invariably enhanced the virus elation in treated hosts.

Post-inoculation sprays of Arsenicum, Thyroidinum and Uranium, each in 7x potency were found to reduce the number of TMV lesions on leaves, while Carcinoxin 1001, Dolichos 7, Morgan 31 and Sulfur failed to produce antiviral effects under similar circumstances (Singh et al., 1980).

Khurana (1980) further recorded the effects of 4 potencies of each of 8 drugs against 6 viruses. Antiviral effects were essentially more on the systemic hosts as compared to the local ones. Thuja, Sulphur and Chenopodium were found to be more effective against CMV, TMV and PVX (Potato virus x) on both systemic and locally reacting hosts. Carbovog., Apis and Bryonia also brought about 50% or more of viricidal effects. Efficacy was usually highest at 30 °C followed by 4 and 200 while 1M of any of the drugs remained practically ineffective.

The tomato strain of TMV (TMV tm), on the other hand was inhibited most by Sulphur 30 (90%) followed closely by Carbo veg. 30 and Chenopodium 30 (75 and 70% respectively)
but not by Apis 30 and Thuja 30 which, however, registered 65% and 80% inhibition of sugarcane mosaic virus (SCMV) and potato virus y (PVy) respectively. Contact spread of mosaic (CMV, TMV, PVy) and leaf curl (Tomato leaf curl virus) diseases in tomato and chilli plants under field conditions were fairly reduced in incidence and delayed expressions in the pretreated plots as compared to untreated ones (controls). Prophylactic treatment of systemic hosts of TMV, PVX and CMV with either of Thuja, Sulphur or Chenopodium (30 potency each) caused 80-90% reduction in virus multiplication and hence delayed the expression as well as severity of the symptoms. Effects were not so pronounced in the post-inoculation phase.

**Homoeodrugs as antifungal agents**

Encouraged by the findings of Verma et al. (1969) and Khurana (1971) on the possibility of controlling plant viruses, Khanna and Chandra (1976) studied the effect of homoeodrugs against certain pathogenic fungi. They found that some of the potencies (between 1-200) of Arsenicum A., Blatta 0., Kali I. and Thuja 0. were antigermatory to the spores of 4 isolates of *Alternaria alternata*. Beside inhibitory effects, Blatta 0.28 caused coiling of the germ tube and its potency 122 as well as Kali I. 143 induced the precocious formation of conidia. Khanna and Chandra (1977) further reported that various potencies of the same drugs either totally prevented spore germination
or mycelial growth of *Pestalotia psidii*, the incitant of guava fruit rot. Furthermore, fruits pretreated with some of the drug potencies escaped infection and therefore, these drugs were recommended as protectants for the disease control (Khanna and Chandra, 1977a). Storage rot of mangoes incited by *Pestalotia mangifera* could also be controlled prophylactically or therapeutically with Lycopodium 190 (Khanna and Chandra, 1978).

Some of the homoeodrugs have also been found to reduce intensity of wheat blight caused by *Alternaria alternata* (Khanna and Chandra, 1977b).

Singh and Gupta (1981) evaluated the efficacy of different potencies of 10 homoeodrugs against *Curvularia lunata* and *Alternaria tenuis*, the common leaf spot disease pathogens of several ornamental and cultivated plants. They reported that Bacilllinum 30, 200, 1000; Lycopodium 200, Fagopyrum 200, 1000; Ustilago 1000, Sepia 30, 200, 1000; Sulphur Iod. 1000 and Mezerium 1000 caused cent percent inhibition of the growth of *A. tenuis* while Fagopyrum 200, Ustilago 6, Petroleum 200 and Sulphur Iod. 6, 1000 brought 100% inhibition against *C. lunata*.

Singh (1983) tested 4 homoeodrugs Bacilllinum, Fagopyrum, Petroleum and Sepia against the radial growth and dry mycelial weight of 4 keratinophilic fungi (*Nannizia incurrata* strain (+), *N. incurrata* strain (-), *Malbranchea*
and *Botryotrichum keratinophilum* and reported that *Fagopyrum* 1000 caused upto 95% inhibition.

Dua and Atri (1983) have also screened five homeopathic drugs viz. *Arsenicum album*, *Blatta orientalis*, *Cina*, *Lycopodium clavatum*, *Thuja occidentalis* against the mycelial growth of *Alternaria solani* and *Botryodiplodia theobromae* isolates of tomato and apple respectively. All the drugs exhibited inhibitory responses. However, *Thuja, Blatta* and *Arsenicum* appeared more remarkable than the others in case of *A. solani*, whereas, in case of *B. theobromae* *Thuja* and *Blatta* proved more effective than others.

Shrivastava and Kushwaha (1984) screened *Lycopodium*, *Ustilago*, *Tellurium* and *Bacillium, 1000* potency each for their effects on growth, sporulation, spore germination and germtube elongation of the skin pathogens, *Microsporum fulvum* and *M. gypseum*. All the drugs were found to generate inhibitory responses. But *Bacillium* was the strongest. It was further suggested that trial of these drugs *in vivo* against skin diseases may reveal an important avenue in the area of medical mycology.

Goswami and Das (1980) are of the view that tuberous begonia plants with shaggy look and stem, leaf rotting symptoms could be saved and recover upon soil drenching treatment with *Thuja Q*. They also found that this treatment
accompanied with foliar spray could combat and prevent the spread of black spot leaf disease of hybrid T roses.

**Homoeoextracts as Pesticides**

Idris (1967), who was the first to try homoeoextracts for the control of plant sufferings, reported that aphid menace on bean plants could be checked if Sulphur 30 is dusted under the plants. Later on Goswami and Das (1980) also reported the control and eradication of scale insects on Cymbidium, an orchid by wetting the infected plants with Staphysagria Q. Certain homoeoextracts can also reduce the natural infestations of aphids and white fly on tomato and chilly plants under field conditions (Khurana, 1980).

Kumar and Sharma (1979) are of the view that nematode diseases of plants could also be controlled by homoeopathic drugs.

**Homoeoextracts as fertilizers**

Khalsa and Khan (1980) have reported their findings based on long term trials in using combination of 7 homoeoextracts in encapsulated form as a substitute for conventional fertilizers. Besides being economical and having longer residual effects in treated fields, the homoeoextract fertilizer was found to improve the soil texture, resulted in early maturity and increased 25-60% yield of crops. They claim upto 80% eradication of plant diseases with homoeoextracts
as compared to the plants cropped with traditional fertilizers.

Idris (1967) has also reported his success in nullifying the ill effects of water logging on papaya with Natrum sulph 30. He further observed that Natrum mur 30 could check the drooping of mango fruits and that kalimur 12 increased their size.

Furthermore, these drugs have also been reported to inhibit the mycelial growth of *Aspergillus parasiticus* as well as the aflatoxin production (Sinha and Singh, 1983).

Dutta (1976, 1979) carried out experiments on wheat plants in water culture with some essential elements in homeopathic potencies. It was found that disease symptoms like, leaf scorch, stunting, curling, yellowing, chlorosis, wilting etc. produced by homeopathic potencies of some essential elements were similar to that of their deficiency symptoms known. Based on these observations he suggested that such deficiency diseases could be cured by specific "proved" essential elements used in homeopathic dilutions in accordance with the basic principles of homeopathy. These findings aptly corroborate not only with the Hahnemannian provings on human beings but are also an extension of the principle of 'similia similibus curentur' to plant world.
The aforementioned abstraction of literature gives a bird's eye view of a few works performed in this area. Nevertheless, it certainly indicates that plant diseases particularly of viral and fungal origins can be controlled by homoeodrugs, that traditional pesticides and fertilizers can be replaced by cheap and harmless homoeodrugs, that crop yields can be improved and that these drugs can also be used in antidoting the toxic secretions of certain fungal pathogens. Homoeodrugs thus fulfil all the prerequisites required of a "genuine alternative". In view of this, three storage diseases were undertaken in the study for their control by homoeopathic drugs. These were, *Alternaria* rot of tomato, *Botryodiplodia* rot of apple and *Rhizopus* rot of brinjal. Available literature does not furnish any evidence as to the site or mode of action of the homoeodrugs against plant pathogens. Therefore, two important physiological processes, namely, respiration and enzymatic degradation of cell walls were also included in the present investigations since disease controlling chemicals are reported to control phytopathogenic diseases either through inactiviting cell wall degrading enzymes (Foote *et al.*, 1949; Horsfall, 1956; Grover and Moore, 1962; Webb, 1966; Mandels and Reese, 1965) or by modulating respiratory metabolism of the pathogen (Sisler and Cox, 1960; Owens, 1963; Erwin, 1973; Vyas and Chaurasia, 1976). The whole work has been planned as follows:
Section I deals with the general introduction and review of literature.

Section II deals with the materials and the detailed methodology required for the isolation of the pathogens, testing their pathogenicity, preparation of the homeopathic drugs, their screening against the mycelial growth of the pathogen, pre- and post-inoculation treatments of the fruits with selected drugs to achieve disease control, and their evaluation on such important physiological processes as respiratory metabolism of the pathogen and the \textit{in vitro} and \textit{in vivo} abilities of the pathogens to degrade cell wall material enzymatically, with a view to understanding their mechanism of action.

Section III deals with the observations, results and discussions pertaining to \textit{Alternaria solani} - tomato, \textit{Botryodiplodia theobromae} - apple and \textit{Rhizopus nodosus} - brinjal systems.

Section IV deals with the general discussions.

Section V deals with the summary and the conclusions.

Section VI deals with the list of references.