IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 18, Issue 4 Ser. 1 (April 2024), PP 69-75
www.iosrjournals.org

Role of Fungicides in Food and Crop Health Security for Better Tomorrow

Dr. Firdos Katiar
Professor, Department of Botany,
Christ Church College, Kanpur, Uttar Pradesh, India

Abstract
Fungicides are absolutely essential for prevention of plant diseases and improving crop yield, which is otherwise lost due to diseases. Their role has assumed importance where desirable host resistance against diseases is lacking. For many of the destructive diseases such as those caused by the members of oomycetes, against which effective host resistance is not available or when the host resistance is easily broken by new pathogen races, fungicides serve as the main method of defense. These diseases were earlier difficult to be controlled by conventional contact fungicides but with the availability of more specific systemic phenylamides and related compounds, it is now much easier to manage them. Likewise, it is now more economical to control diseases like powdery mildew, rusts, smuts, bunts, apple scab, cercospora blights, etc., with triazoles and related EBI fungicides at much lower doses than earlier compounds due to their broad spectrum activity. Internally seed borne pathogens like smuts, bunts, etc., can be effectively controlled by seed treatment with systemic fungicides with negligible expenses on the treatment. It is undoubtedly evident that the use of fungicides has enhanced economic returns of the farmers. In most of the spray applications, the increases in yield that can be attributed to fungicide usage are, on an average, worth at least three times the cost of the inputs which can go as high as more than ten times in case of seed treatments. In addition, the farmer gets a healthy blemish-free crop produce, which carries much significance in context with the WTO regime. No ill or adverse effect of fungicides on human health, environment and ecosystem occurs if the pesticides are used ethically following guidelines provided by Pesticide Action Network (PAN), Fungicide Resistance Action Committee (FRAC) and scientists. The ill effect ever witnessed is due to man's folly and pesticides cannot be blamed for the hazards. However, to minimize the hazards and to prevent ecological disruption, making disease control cost effective and socially acceptable, fungicides can be used as an integral part of IDM system.
Keywords: *Fungicides, disease management, food and healthy security*

I. INTRODUCTION

The predicted growth of world's population from 7 billion at present to 8.3 billion by 3030 presents a major global challenge to meet necessary food demand. At the same time, per capita farmland is decreasing drastically. This will result into increased demand for food, feed and fiber. India has produced 240 mt of food grains during 2010-11 and with the increase in rate of population growth, it would require about 400 mt by 2050. Plant diseases are estimated to cause yield reductions of almost 20% in the principal food and cash crops worldwide. Of the over 100,000 described species of fungi in the world, approximately, 20,000 produce one or more diseases in various plants [1].

Although losses due to plant diseases may be reduced with the use of disease resistant varieties, cultural and biological practices, fungicides are often indispensable to maximize crop yields and improving food quality. They contribute to crop health security by managing devastating diseases in agricultural crops. In USA alone, growers apply fungicides for controlling more than 200 diseases of 50 crops in the field. Fungicides are now considered to be the second line of defense in plant disease control programs after disease resistance. We need to use the right fungicides in the right amount and increase our crop yields.

DEVELOPMENTS IN FUNGICIDE – PAST TO PRESENT

The development of fungicides for controlling plant diseases has passed through several stages. Generally, the type of materials developed corresponded with the knowledge of disease etiology and also the chemical and biological properties of the compounds. Initially, simple inorganic chemicals were put to use, but as our understanding of pathogenic processes increased, more complex organic compounds were developed with enhancing efficacy. Several incidents of devastating effects of diseases in the earlier times prompted the growers to try various rudimentary chemicals like sulphur lime, sodium chloride, sodium sulphate, etc. [2]. The real interest in the development of fungicides started with the discovery of Bordeaux mixture by Millardet in 1885 for the control of grape downy mildew in France [3]. Bordeaux mixture belongs to first generation of fungicides along with other inorganic chemicals. Up until the 1940s, chemical disease control relied upon inorganic chemical preparations frequently prepared by the users. From 1940 to 1960 there were a number of new chemistry classes introduced as fungicides. The dithiocarbamates and the later phthalimides represented a major improvement over the previously used inorganic fungicides in that they were more effective, less phytotoxic and easier to prepare by the user. The second generation of fungicides, which are organic chemicals, dates from 1934 with the development of dithiocarbamates along with organotins, low soluble copper compounds, captan, quinines and related compounds chlorothalonil and pentachloronitrobenzene. These compounds were all surface protectants like the inorganic fungicides. The decade from 1960 to 1970 saw a rapid expansion of research and development along with a rapid growth of fungicide markets. In this decade, the most widely used protectant fungicides, mancozeb and chlorothalonil were introduced. The decade also gave us the first systemic seed treatment compounds carboxin and oxycarboxin for controlling seed borne smuts, foliar rusts in cereals and assorted Rhizoctonia infections and also the first broad spectrum systemic fungicides group benzimidazoles (benomyl, carbendazim, thiobendazole). The more important third-generation fungicides were introduced since 1970. These modern fungicides were also organic but could penetrate the plant tissue, i.e., systemic and control established infections. These included dicarboxamides (iprodione, vinclozolin), organophosphorous compounds (edifenphos, iprobenphos), triazoles (propiconazole, triadimefon, flusilazole) imidazoles (benalaxyl, oxidaxyl) Phenylamides (metalaxyl, benalaxyl), alkylphosphonates (fosetyl-Al), cyanoacetamideoximes (cymoxanil), morpholines (tridemorph, fenpropimorph) and 2-aminopyrimidines (ethirimol, dimethirimol). There was a drastic reduction of use rates per hectare as more effective and selective fungicides were introduced over this time. For instance, the current use rates of below 100 g/ha for many triazoles against the same pathogen is a 200-fold reduction. The fourth generation of fungicides consists of compounds that are ecologically safe, have still new modes of action, somewhat broad spectrum and are applied at quite low dose rates. Examples of these are strobilurins (azoxystrobin), oxazolidinediones (famoxadone), phenoxyquinolines, (quinoxyfen), anilinopyrimidines (cyprodinil, pyrimethanil), valinamides (iprovalicarb, benthiocarb) mandelamides, (mandipropamid), phenylpyrroles (fenpicloil, fludioxonil), spiroketalamines (spiroxamine) representing different modes of action. Majority of these have been developed for use against oomycete pathogens thus indicating the necessity to manage these pathogens.

The strobilurins are an outstanding new class of fungicides, which control diseases caused by pathogens from class oomycetes, ascomycetes, basidiomycetes and deuteromycetes. Safety wise, EPA considers them as reduced risk pesticides, posing less risk to human health and/or the environment than alternative pesticides available at the time of their introduction. Their rapid degradation in soil makes them environmentally benign. Strobilurins can now be considered to be one of the most valuable classes of fungicides ever discovered by the agrochemical industry. Arrival of strobilurins may be fortuitous making the beginning of an era of exciting new-generation fungicide with immense potential of plant disease control. Though resistance development is a problem, it can be managed by following FRAC guidelines and restricting foliar application to one in the season. More recently used strobilurins after azoxystrobin are kresoxim methyl, trifloxistrobin, pyrachlostribin and more recently fluoxasrobin [4].

Fungicides in Indian Agriculture

A number of fungicides belonging to different chemical groups have been registered in India and these are being used against diverse diseases in crops. Fungicides, namely, sulphur, dithiocarbamates, copper based, phthalimides, benzimidazoles, phenylamides, triazoles, etc., are now regularly used in Indian agriculture, with the use of costly specific fungicides for high-value crops only. As on 20.01.2012, a total of 65 antifungal products have been registered in India including four antifungal/antibacterial antibiotics and four biocontrol agents [5].

Among various fungicides used in India, consumption of mancozeb is the highest followed by sulphur compounds, copper oxychloride, copper sulphate, carbendazim and thiram as per the demand pattern [6]. These six fungicides constitute more than 84% of the total fungicides used with mancozeb alone accounting for 25% of the total hexaconazole, propiconazole, metalaxyl-M + mancozeb, cymoxanil + mancozeb, edifenphos, triadimefon, tricyclazole and azoxystrobin are few other fungicides that account for substantial fungicide market in India. Crop-wise consumption of fungicides in India is maximum on pome fruits, followed by potatoes, rice, tea, coffee, chilies, grapevines, other fruits, vegetables and field crops [7].

Apart from contact fungicides like sulphur, dithiocarbamates, copper based, mercurials, phthalimides, etc., several of the site specific fungicides of the groups like benzimidazoles, oxathins, thiophanates, organophosphorus, triazoles and related sterol inhibitors, phenylamides and some other fungicides are also being used in India for controlling diseases on a number of crops. Some of the new generation fungicides have also been registered in India for use against different diseases. These are mentioned in Table 1.

Table 1: New-Generation Fungicides Registered in India.

Fungicide group	Name of fungicide	Effective against
Strobilurins	Azoxystrobin, kresoxim methyl, trifloxistrobin, pyrachlostribin	Powdery mildew, downy mildew of grapevine, cucurbits, rice sheath blight
Valinamides	Iprovalicarb, benhiovalicarb	Oomycete diseases in grapevine , cucurbits, potato and tomato
Imidazoles	Fenamidone	Potato late blight and grape downy mildew
Oxazolidinediones	Famoxadone	Potato late blight
Mendelamides	Mandipropamid	Late blight of potato and Downey mildew of grapevine
Melanin biosynthesis inhibitors	Carpropamid	Rice blast

Role of Seed Treatment

Seed treatment with fungicides is one of the means of achieving ecological sustainability. It is an ecofriendly way of managing regular diseases of crops during and immediately after germination, thereby ensuring optimum crop stand, which is essential for good crop harvest. There are several examples where crops had to be resown for want of proper protection after germination. A good range of seed treatment fungicides is now available ranging from the traditional chemicals like thiram, captan, mancozeb, carbendazim and carboxin to the more effective and safer compounds such as mefenoxam + fludioxanil and azoxystrobin, pyraclostrobin + metaconazole developed during 2008–10.

Nationwide, 70% requirement of seeds is met from the farmer's own seed stock most of which is sown without any seed treatment. Even if seed is purchased from the private or public sector agencies, large percentage of such seed is untreated. The estimates further reveal that on an average, 80% of the seed sown in the country is untreated, as against the 100% seed treatment practice in developed countries [1]. This may be one of the several reasons for our lower productivity in many crops compared to developed countries. There is thus an ample scope of improving our crop yields through appropriate seed treatment practices.

Green Chemicals

Recent generation of molecules for plant disease control consists of those compounds which are not fungicidal as they exhibit little or no fungitoxicity in vitro condition. They manage the disease by their novel mode of action either interference with processes involved in fungal penetration into the plants (antipenetrants) or by enhancing host defense resistance (defense inducers). These compounds, viz., probenazole, acibenzolar–S-methyl, tricyclzole, pyroquilon, carpropamid, pp389, edifenphos, IBP, salicylic acid, jasmonic acid, fosetyl–Al, etc., are effective at low concentration [8]. Compounds that trigger host defense activity are less likely to encounter problem of development of resistant strains than conventional systemic fungicides because (a) they exert less selection pressure on the pathogen, (b) they act by inducing hosts general defense mechanisms. These compounds are potentially very valuable since the side effects on microbial population in the environment are less severe than those produced by conventional fungicides. They are called "green chemicals" because of their environmental friendliness. Probenazole is a systemic compound that indirectly controls rice blast and some bacterial rice diseases by stimulating the accumulation of toxins and enzymes associated with systemic acquired resistance in rice, but is ineffective in other cereals. Acibenzolar–S-methyl (Actigard) has the widest spectrum of activity among the non-fungitoxic compounds developed to date. It is active against various fungi, bacteria and viruses in several crops and stimulates plant's natural defense system when applied a week of infection [9]. Such compounds with indirect action against the pathogens are likely to gain prominence in future crop protection.

Fungicide Mixtures

Fungicide mixtures, containing two or more fungicides with different modes of action, have been developed with the twin objectives of broadening the activity spectrum against diverse plant diseases and to check the development of resistance in the target pathogens. In recent years, several prepacked mixtures of specific site and contact fungicides have been introduced by different manufacturers. Theoretically, the use of prepacked mixtures offer several advantages: (a) the protectant component should control the resistant isolates; (b) the dose of the systemic component may be reduced to additive or synergistic levels; (c) reduced concentration of systemic component should reduce the selection pressure for resistance; (d) multiple disease control; and most importantly (e) the use of prepacked mixtures is an enforceable strategy. Some of the recently developed and commonly used fungicide mixtures are depicted in Table 2.

Table 2: Some of the Recently Developed Fungicide Mixtures.

Commonname	Name of fungicide mixtures'	Effective against
Ridomil Gold	Mefenoxam + Ancozeb	Downy mildew, *Pythium* and *Phytophthora* diseases
Input	Prothioconazole + Spiroxamine	Powdery mildew, *Fusarium*, *Septoria*, rusts in cereals
Twinline	Yraclostrobin + Metaconzole	Cereal rusts
Amistar Top	Azoxystrobin + Difenoconazole	Various diseases on diverse crops
Prosaro	Prothioconazole + Tebuconazole	*Fusarium* head scab in cereals
Luna Sensation	Fluopyram + Trifloxystrobin	Gray mold, powdery mildew, *Sclerotinia* and *Monilia* in fruits

Role of Disease Monitoring

Disease monitoring plays a significant role in preventing epidemics. The foremost objective of any disease monitoring program is forecasting of disease development conditions and the most valuable suggestion based on it is timely advice to initiate sprays of fungicides [13]. Disease monitoring forms the backbone of any disease control program. It provides information on the disease progress curves necessary to construct models and supplies on the simulator data on the variables involved in the development of epidemic [14].

Role of Disease Forecasting

Development of disease forecasting systems is perhaps the most important application of epidemiology which has helped growers in taking decisions regarding chemical disease management with greater precision. Their acceptance by the farmers depends largely on features such as reliability, simplicity, usefulness, applicability to important diseases and most importantly the cost effectiveness [15]. The efficiency of a protective fungicide (Dithane M-45) used for the control of potato late blight was enhanced when applied according to a forecasting model “Blitecast” than if applied after each 1.27 cm of rain [16]. The protective fungicides such as Dithane M-45 provide desirable protection only when used as prophylactic sprays. Under high disease pressure conditions, only systemic fungicides Ridomil MZ with excellent curative properties can check the disease whereas under low disease risk situation, their use may be just superfluous which can be avoided. [17]. The study highlights the importance of appropriate timing of fungicide application as well as the choice of fungicides in better disease management.

Fungicide Residues

The residue levels of certain fungicides in the soil or edible plant parts may sometimes be well above the acceptable limit and this varies with the dose of the fungicides used along with total number of sprays done. With the over use of systemic fungicides for managing diverse fungal diseases in agricultural crops, there are ample chances of their residue buildup in harvested produce. Not adhering to the recommended pre-harvest interval may further compound the problem. This not only poses health risks to consumers, but may also affect the export potential of certain commodities to the developed countries. Detection of residues of carbendazim and isoprothiolane above MRLs in basmati rice consignments exported from India to Germany in 2010 and that of tricyclazole in the consignments exported to USA in 2011 has sent warning signals among the agriculturists and trades in India. Modern HPLC technology makes it possible to detect very small amounts (in ppb) of the fungicides in the food products. Farmers need to be educated to follow the recommended guidelines while using fungicides and other pesticides.

Importance of Spraying Technology

The importance of spraying technology is no less than effective fungicides but field of plant protection equipment is most neglected. Unfortunately, till now fungicides are developed, recommended and sold without adequate research on application equipment or technique. Most of the commercially used spray equipment is inefficient and spray particle deposition efficiency is less than 20%. At present, most of the droplet size is bigger. Larger droplets which are transported by gravitational fall cannot reach pest microhabitats and constitute mainly economic waste and major source of ecosystem contamination. Droplets less than 100 micron diameter are transported in significant mass and number into the microhabitats of various pests. But only a few number of LV and ULV formulations of fungicides are available. At the same time, fine droplets are more apt to drift and evaporation. Under these circumstances, it is imperative to recommend optimum spray technology along with the pesticide recommendation. It will prove economically viable and ecologically safe under Indian conditions.

Non-target Effects

Though fungicides are primarily used to manage plant diseases caused by different kinds of pathogens, these may, sometimes, exert adverse effects on other microbial flora and fauna some of which may be beneficial to crop plants. Many organic fungicide products can provide effective disease control with minimal ecological impact. However, injudicious use of any fungicide will result in poor control and may harm non-target organisms. Besides affecting plants, some fungicides can adversely affect soil microflora. The fungicides, propiconazole and triadimefon, on repeated use, could modify the soil microbial ecology over a longer period of time [18]. Soil microbial populations including various fungi and denitrifying bacteria are also greatly affected by the application of mancozeb [19]. Similarly, fungicides like benomyl, furalaxyl, thiram, and mepronil also affect symbiotic relationship between the plant and mycorhizae. Fungicides may also pose potential environmental and human health hazards.

Spurious Fungicides

One of the problems faced by poor farmers is the substandard/spurious fungicides. It is estimated that spurious pesticides account for about Rs. 1000–1200 crore. of sales. Farmers not only lose their investment on fungicides, but because spurious fungicides do not control the diseases, the farmers lose their crops also. Here again, the agriculture department should play their role effectively by being vigilant, nab the culprits and punish the producers and sellers of spurious pesticides so that this menace is totally eliminated to save farmers.

Fungicide Resistance

Fungicides continue to play a key role in strategies for the control of diseases in crops, and the development of resistance in the target pathogens is a continuing risk. Resistance occurs when a pathogen becomes so insensitive to a fungicide that the fungicide's field performance is diminished, in some cases to the point where it could be completely ineffective. Pathogens respond to the use of fungicides by evolving resistance. In the field, several mechanisms of resistance have been identified. The evolution of fungicide resistance can be gradual or sudden. In qualitative or discrete resistance, a mutation (normally to a single gene) produces a race of a fungus with a high degree of resistance. Such resistant varieties also tend to show stability, persisting after the fungicide has been removed from the market. For example, sugar beet leaf blotch remains resistant to azoles years after they were no longer used for control of the disease. This is because such mutations often have a high selection pressure when the fungicide is used, but there is low selection pressure to remove them in the absence of the fungicide. In instances where resistance occurs more gradually, a shift in sensitivity in the pathogen to the fungicide can be seen. Such resistance is polygenic – an accumulation of many mutations in different genes each having a small additive effect. This type of resistance is known as quantitative or continuous resistance. In this kind of resistance, the pathogen population will revert back to a sensitive state if the fungicide is no longer applied. Little is known about how variations in fungicide treatment affect the selection pressure to evolve resistance to that fungicide. Evidence shows that the doses that provide the most control of the disease also provide the largest selection pressure to acquire resistance, and that lower doses decrease the selection pressure [13].

In some cases, when a pathogen evolves resistance to one fungicide it automatically obtains resistance to others – a phenomenon known as cross resistance. These additional fungicides are normally of the same chemical family or have the same mode of action, or can be detoxified by the same mechanism. Sometimes, negative cross resistance occurs, where resistance to one chemical class of fungicides leads to an increase in sensitivity to a different chemical class of fungicides. This has been seen with carbendazim and diethofencarb. There are also recorded incidences of pathogens evolving multiple drug resistance – resistance to two chemically different fungicides by separate mutation events. For example, Botrytis cinerea is resistant to both azoles and dicarboximide fungicides. There are several routes by which pathogens can evolve fungicide resistance. The most common mechanism appears to be alteration of the target site, particularly as a defense against single site of action fungicides. For example, black sigatoka, an economically important pathogen of banana, is resistant to the QoI fungicides due to a single nucleotide change resulting in one amino acid (glycine) being replaced by another (alanine) in the target protein of the QoI fungicides, cytochrome b [10]. This presumably disrupts the binding of the fungicide to the protein, rendering the fungicide ineffective. Upregulation of target genes can also render the fungicide ineffective. This is seen in DMI resistant strains of Venturia inaequalis [11]. Resistance to fungicides can also be developed by efficient efflux of the fungicide out of the cell. Septoria tritici has developed multiple drug resistance using this mechanism. The pathogen had five ABC type transporters with overlapping substrate specificities that together work to effectively pump toxic chemicals out of the cell [12]. In addition to the mechanisms outlined above, fungi may also develop metabolic pathways that circumvent the target protein, or acquire enzymes that enable metabolism of the fungicide to a harmless substance. Usually resistance against benzimidazoles, phenylamides, carboximides and aromatic hydrocarbons is controlled by major gene(s). Minor genes (polygenes) controlled resistances are reported for dodine, ergosterol biosynthesis inhibitors and cycloheximides.

Fungicide Resistance Management

The Fungicide Resistance Action Council (FRAC), an organization of scientists from manufacturers of the at-risk fungicides, has recommended guidelines for reducing the risk of resistance development. The FRAC guidelines, if followed rightly, can certainly reduce the risk of resistance development. The guidelines are as follows.

- The fungicides should be rotated with safe, broad spectrum fungicides.
- They should not be used alone but as mixtures of fungicides belonging to different groups.
- "At risk" fungicides must be used only when it is absolutely necessary.
- These fungicides should be used early, before the chances of disease development, and when the pathogen population is small.
- The number of applications per season and the dose should be limited.
- Avoid use of fungicides in areas where resistant races to that group of fungicides are documented.
- Instructions from the manufacturers regarding rate and application interval should be strictly followed.

Role of Fungicides in IDM

The fungicide will remain a major component in IDM. The use of fungicides should be selective and based on economic threshold levels. It is a cause of concern that message of IDM is not reaching the stakeholders in true sprit as was desired and thought upon. IDM without fungicide has no meaning as the other components are not fully equipped to tackle the epiphytotic of diseases, besides the availability of biotic agents is questionable.

Symphony amongst Pesticide Users and Promoters

It is beyond doubt that fungicides are the most important means of controlling plant diseases to ensure food security. But the desired symphony amongst the four players – the growers, the extension worker/scientist, the industry, and the press responsible for disseminating the knowledge – is lacking, which needs strengthening. Each element has to play its role to make disease control a grand success. The role of the fourth estate, i.e., the media or the press, is very wide. If briefed properly, it can work wonders by exposing myths on pesticides. The extension workers, scientists, and industry have the benign responsibility of involving the press and projecting the true perspective and reasons for unexpected hazards. We are required to bring media closer rather than keeping them at a distance.

The Benefits and Risks of Fungicides

The application of any chemical to a crop or food raises the question of risks and benefits. Overall, the benefits of fungicides far outweigh the risks, if they are used carefully and according to the label recommendations. Currently, more than 80% of the fruit and vegetable crops grown in the USA receive a fungicide use. In the USA, agriculture is reported to boost farm income by nearly 13 billion dollars annually. In general, cost benefit ratio of fungicide spray application in managing foliar, diseases comes out to be 1:3 in most of the cases, which is still much higher in case of seed treatment.

Safety and Precautions

Fungicide usage in India is expected to increase in the coming years. One of the reasons is the policy of the Indian government to encourage the export of agricultural commodities, mainly from horticultural segment. Generally, disease problems are more in horticultural crops. Hence the scope for increased use of fungicides is quite high. In addition, farmers in this segment are relatively better informed and aware about the importance of diseases and the benefits derived out of the control of diseases. As these crops are high-value commercial crops, farmers do not mind spending on fungicides.

One of the important tasks in the safe use of fungicides is educating the farmers in the judicious use of fungicides. Whatever the problems encountered by farmers in disease control, these are mainly due to lack of knowledge on the correct usage of fungicides. The four key points (four R's) to be followed for a proper and safe use of fungicides are:

- Right Chemical: Very important, as the wrong diagnosis leads to a selection of wrong chemical and failure of disease control.
- Right Dosage: Most of the farmers in India do not apply correct recommended dosage, apply mostly sub-lethal dose or sometimes over dose which results in the buildup of resistance by the pathogens, further aggravating the problem.
- Right Coverage: Very much required in the case of protective fungicides. Good coverage by using optimum spray fluid with good spray equipment will give effective control of diseases.
- Right Timing: Depending on the nature of fungicide, viz., protectant, eradicant or curative, the chemical has to be applied at the right time, to get the best out of it.

CHALLENGES FOR THE FUTURE

- Presently, not much work on fungicide residues is being done in India and most of the laboratories are engaged in work on insecticide residues. It is now imperative to produce residue-free crops for exporting to other countries and it warrants setting up of fungicide residue laboratories in different states of India so that systemic work on this important aspect could be taken up.
- Technologies need to be developed for integration of fungicides with biocontrol agents to minimize their use.
- Research needs to be strengthened to explore the potential of plant-based chemicals for the control of plant diseases as India is a store house of diverse plant species and extracts/oils of many species are known to possess antifungal and antibacterial properties.
- Some agrochemical companies have recently introduced ecofriendly compounds derived from microbial species and these can be tried in India as well in order to replace existing more toxic compounds

II. CONCLUSIONS

In the last two decades, there have been numerous discussions to formulate strategy with respect to the role of fungicides in human and plant health. It cannot be disputed that fungicides did play a vital and significant role in increasing and stabilizing food grain production of the world. In fact, the success of green revolution depended much on chemicalization of agriculture. However, indiscriminate/injudicious use of fungicides led to several environmental, ecological, social and economical problems, and they warranted attention. The debate started whether to ban fungicides, to continue their use or popularize need based/judicious use of fungicide. All three options deserve serious consideration and their merits and demerits must be thoroughly known to reach some definite conclusions.

Fungicides have caused health hazards, environmental pollution, recurrence/resurg-ence/resistance in pests/pathogens, soil health problems and so forth. But the question arises as to why these hazards and mishaps occurred and what are the real reasons behind such happenings. The analysis of the facts reveals that fungicides as such are not the culprits. It is their continuous, indiscriminate and unscientific use that has created that problem; everyone including administration, marketing focus and the farmers are responsible for such happenings.

We cannot avoid the use of pesticides in the coming decades because

- Food grain production must continue to rise to feed ever-growing human population.
- Intensive agriculture does not allow management through cultural practices and plant genotypes having high input response must be protected.
- Over 30% losses to plants and their products being caused globally by pests must be contained.
- No better options to manage the pest damage are available. Factually speaking, we do not have any other adequate option to deal with the pests. The farmers require immediate action and at present the fungicides remain the only relief.

In view of the current status of fungicides and their intense level of utilization, it is unrealistic to think of banning the fungicides. Use of fungicides will continue but emphasis should be on need-based judicious use, that too under IDM umbrella.

REFERENCES

[1]. Thind T. S. Indian Phytopathology 2012; 65(2):109–115p.
[2]. Hewitt H. G. Fungicides in Crop Protection. CAB International Wallingford, U.K. 1998; 221p.
[3]. Millardet P.M.A, Gyan U. Journal of Agricultural Practices 1987; 51:123–129p, 151–161p.
[4]. Srivastava M.P. www.xsgrowth.com. 2008
[5]. Thind T. S. Indian Phytopathology 2007; 60(4):421–433p.
[6]. Agnihotri N.P. Pesticide Research Journal 2000; 112:150–155p.
[7]. Thind T. S. One Hundred Years of Plant Pathology in India: An Overview. Scientific Publishers, Jodhpur. 2005; 267–305p.
[8]. Chaube H. S, Singh U.S. Plant Disease Management: Principles and Practices. CRC Press. New York. 1990; 329p.
[9]. Leadbeater A, Staub T. In: Induced Resistance for Plant Defence. D. Walter, A. Newton, G. Lyon (Eds). Blackwell, Oxford , U.K. 2007; 229–242p.
[10]. Metcalfe. Plant Pathology 2000; 49:546–557p.
[11]. Sierotzki Helge. Pest Management Science 2000; 56: 833–841p.
[12]. Schnabel G., Jones A. L. Phytopathology 2001; 91:102–110p.
[13]. Threshs J.M. Annual Review of Phytopathology 2007; 12:111–128p.
[14]. Young C, Prescott J.M., Saari E.E. Annual Review of Phytopathology 1978; 16:263–285p.
[15]. Fry W.E. Principles of Plant Disease Management. Academic Press, New York, U.S.A. 1982.
[16]. Fry W.E. Phytopathology 1977; 67:415–420p.
[17]. Thind T.S, Singh P.P, Sokhi, et al. Plant Disease Research 1991; 6:49–53p.
[18]. Jui Hui-Hung, Y. Jin-Shu C, Pin-Jui H, et al. Journal of Environmental. Science & Health 2009; 44:681–689p.
[19]. Pozo C, Rodelas B, Salmeron V, et al. Journal of Toxicological. Environmental Chemistry 1994; 43:123–132p.