**Department of Plant Pathology**

**College of Agriculture, Rewa (M.P.)**

Class : M. Sc.(Ag) Previous

Subject : **Seed Health Technology (PL.PATH 510)**

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**Lecture 13 – Toxic metabolites affecting seed quality and its impact on human, animal and plant health**

**Toxins**

Toxins are low molecular weight compounds (metabolites) produced by microorganisms that are toxic to plant and animals. These are important in necrotrophic phase (virulence factor) rather than in biotrophic phase (pathogenicity factor). All the toxins isolated so far are from saprophytic pathogens. No toxins has been isolated from obligate parasites like rusts, powdery mildew, downy mildew etc.

Toxins are compound produced by a microorganism which is toxic to plants (Diamond and Waggoner, 1953)

**Classification of toxins**

**On the basis of *their role in pathogenesis***

1. **Pathotoxins :** It is general term used for phyto-toxic substances produced by pathogenic microorganisms. These are primary determinants (initiation) of disease and the pathogenicity. Pathotoxin induces all the typical symptoms in reasonable concentrations and is correlated with pathogenicity. Host specific toxins are considered as pathotoxins. **Ex. H.V. toxin, T. toxin, A.M. toxin**
2. **Phytotoxins :** Toxins produced by pathogens, which are toxic to host and non-host plants are known as phytotoxins**.** Non-specific toxins are considered as phytotoxins. These toxins are required for virulence and are important for secondary determinants(disease inducing). These toxins are not essential for colonization. **Ex. Tab-toxin, Ten-toxin, Phaseolotoxin.**

**3. Vivotoxins :** The toxin produced *in vivo* (in the infected tissues) and functions in disease development, but not as the initial inciting agent. Ex. **Fusaric acid, pyricularin**

**On the basis of specificity to host (Scheffer, 1983)-** classified as

1. **Host specific toxins:** Toxins which are toxic to only specific host plant or species or varieties and completely harmless to others are known as host specific toxins or host selective toxins or pathotoxins . Ex. H.V. toxin, T. toxin, A.M. toxin
2. **Non-specific toxins :** Toxins which are toxic to both host and non-host crops are known as non-specific toxins. These are also known as phytotoxins or General toxins. Ex. Tab-toxin, Ten-toxin, Phaseolotoxin.

**Effect of toxins on host tissue**

* Changes cell permeability
* Disruption of normal metabolic activity
* Loss of salts from protoplasm increases
* Affect Respiration
* Uncoupling of oxidative phosphorylation
* Inhibition of host enzyme
* Affect cellular transport system e.g. H+/K+ exchange at the cell membrane
* Interfere with growth regulatory system e.g. inhibition of root growth

**Toxin-producers**

* **Some bacteria** e.g., *Pseudomonas, Burkholderia, Clavibacter, Streptomyces, Xanthomonas*
* **A number of fungi**: *e.g. Alternaria, Ascochyta, Bipolaris, Botrytis, Cercospora, Cochliobolus, Colletotrichum, Drechslera, Fusarium, Phoma*

**MYCOTOXINS**

The word **mycotoxin** is denoted to the fungal secondary metabolites that are injurious to the health of animal and humans. It is derived from the

Greek word *mykes* means fungus and

Latin word *toxicum* means poison

Diseases caused due to mycotoxins are refereed as **mycotoxicoses**

* More than 300 mycotoxins have been described belonging to several chemical groups and their structural formulae have been confirmed.
* Cereals and oilseed are especially prone to mycotoxin contamination

**Significance of mycotoxins**

**I. Effect on human health :** Mycotoxins exhibited very deleterious effect on human health. The mycotoxins have been found associated with the degeneration and malfunctioning of kidney, disorders if respiratory system especially in lungs and bronchitis, adverse effect of liver functioning & related metabolism, toxic hepatitis, cardiac problems, esophageal abnormalities, fever, reduced mental alertness & cervical problems.

**II. Effect on animal health :** Consumption of mycotoxin contaminated feed results in low productivity, determined quality of milk, egg and meat of animals. The medicines are ineffective in mycotoxicoses and animals are prone to outbreak of other diseases. Ex. Turkey X disease caused by Aflatoxin

**III. Seed and seedling diseases:** Mycotoxin inhibits the seed germination and emergence. Abnormal elongation in lettuce hypocotyls, reduced chlorophyll and nucleic acid synthesis in maize has been reported. Heavily infected seeds of soybean, groundnut and maize with *Aspergillus flavus* exhibit total seed rot.

**IV. Phytosanitary regulations:** With the emergence of WTO, the trade of mycotoxin free seeds, planting material, processed food and feed has assumed a greater significance. For the production and marketing of an end product extreme care is an obligatory measure and no-toxin certificate are mandatory. The import-export of the commodity is adversely affected due to fungal infection

**Ex.**

1. **Aflatoxin**  is Carcinogenic (causes cancer) ,Teratogenic (causes birth defects) and causes acute illnesses with flu symptoms, convulsions, paralysis, coma and death
2. **Ergot Toxin**—an alkaloid Highly Stable molecule Also Heat Stable withstands long storage withstands brewing processes withstands boiling  
   **Target organs**—brain, nerve & muscle tissue, circulatory and endorcrine systems

**Symptoms** - Flu like symptoms, mental confusion and hallucinations (LSD), limb paralysis, abortion, seizures, dry gangrene due to vasoconstriction, death

**Important toxins produced by microorganisms**

|  |  |  |
| --- | --- | --- |
| Toxin | Produced by | Disease |
| Phaseotoxin,Phaseolotoxin | Pseudomonas syringae pv phaseolina | Halo blight in beans |
| Tab-toxin (Wild fire toxin) | Pseudomonas syringae pv tabaci | Wild fire of tobacco |
| Amylovorin | *Erwinia amylovora* |  |
| H.V. Toxin | *Helminthosporium victoriae* | Oats Victoria blight |
| Fumaric acid | *Rhizopus spp* | Almond hull rot |
| Ophiobolin | *Cochliobolus* spp | Blight of cereals |
| Ceratoulmin | *Ceratocyctis ulmi* | Dutch elm disease |
| Cyclopiazonic acid | *Aspergillus tamari* | Kodo millet & other cereals |
| Aflatoxin | *Aspergillus flavus* | Kodo millet & other cereals |
| HS Toxin | *Cochliobolus sacchari* | Sugarcane |
| ACL Toxin | *Alternaria citri* (lemon race) | Rough lemon |

**Important Mycotoxicoses**

|  |  |  |  |
| --- | --- | --- | --- |
| Mycotoxicoses | Causal organism | Toxins produced | Affected ones |
| Ergotism | Sclerotia of Claviceps spp. | Ergotin | Man , cattle, sheep, horse, poultry pigs |
| Afla-toxicoses | *Aspergillus flavus*  *A. parasiticus* | Afla-toxin B1, B2, G1 & G2 | Man  Turkey X disease in poultry birds |
| Nephro-toxicoses | *Aspergillus ochraceus*  *Penicillium viridicatum,*  *P. citrinum, P. expansum* | Ochratoxin  Citrinin | Animals (pigs) |
| Fusariotoxicoses | *Fusarium sporotrichioids* | Fusariogenin | Man (Septic angina)  & animals (horse,cattle, pigs) |
| Pink rot dermatitis | *Sclerotinia sclerotiorum* | Psoralens | Man |
| Lupinosis | Phomopsis leptostromiformis | Hepatotoxin | Sheep, cattle, Horse |
| Red Tide  (Algae) | *Glenodium* spp., *Gymnodinium* spp, *Gonyaulox* spp | Neuro-toxin | Human |

**Mycotoxins have been grouped according to their ecological origin**

Many fungi both field and storage fungi produce metabolites that are poisonous, some times fatal to man and animals.Production of these metabolites (mycotoxins) depends on species or strain of the fungus and on the ecological conditions for its development particularly food source.

1. **Mycotoxins produced by field fungi.**
2. **Mycotoxins produced by storage fungi**
3. **Mycotoxins produced by field fungi.**

**Ergotism :** Poisoning due to the effect of various alkaloids in the slerotia of *Claviceps* spp.. Toxins from C. paspali cause damage to the nervous system of domestic animals including horse, mule, pig, sheep and cattle. The disturbance results in trembling and uncoordinated movement, paralysis and death. This condition is known as *Paspalum staggers*.

The ergot alkaloid produced by *C. purpurea*. The effects of the poison in man ranges from vomiting lesions on the hand and feet, diarrhea, impairment of mental function, endocrine imbalance leading to foetal disturbance, agalactia in man, cattle, sheep, poultry and pigs are sensitive to poison. It has a contractile effect on the uterus and in circulative system and culminates in gangrene developing as tissue necrosis of the extremities and the end of the tail.

The ergot alkaloids have for long been utilized in medicine in child birth and treatment of migraine. In recent years, large scale production of semi synthetic alkaloids has been based on lysergic acid gained from C. paspali. LSD is a modified form of lysergic acid.

1. **Mycotoxins produced by storage fungi**

**Aflatoxicosis** in man and animals is caused by a series of toxins viz. aflatoxin B1, B2, G1 and G2 produced by *Aspergillus flavus*, *A. parasiticus*. The first recorded incitant of animal poisoning is known as *Turkey X disease* and occurred in England in 1960. When aflatoxicosis caused heavy losses of turkey poults and other poultry. The effect of aflatoxin includes acute toxicity and carcinogenic activity.

**Nephrotoxicosis** in animals particularly in pigs. Nephrotoxins are produced by different species of *Aspergillus* and *Penicillium*.

Ochratoxin complex by *Aspergillus ochraceus*

Citrinin by *Penicillium viridicatum, P. citrinum, P. expansum*

Citrinin is found in nature in yellowed rice invided by the fungi of this group. P. viridicatum appears to be the main producer of citrinin in cereals. The effects of the toxins are depression of the growth rate, increased water consumption and diaresis, chronic damage to the kidney.

**Fusariotoxicoses-** In man and animals. Potentially very dangerous to man is **Fusariogenin** from *Fusarium sporotrichioids*. The toxin is produced in various cereals in particular millets and maximum production takes place at 0 – 50C. Humans are very susceptible to this toxin but also horses, cattle and pigs are affected. The disease was detected in Russia under extreme circumstances during world war II. Many people became ill and thousands died from a disease called *Alimentary toxic aleukia* (ATA) or *Septic angina*, after consumption of affected flour of grain millets.

**Pink rot dermatitis** in man may be incited by a mycotoxin containing psoralens produced by *Sclerotinia sclerotiorum* causing pink rot of celary. It produces blisters on skin. The severe dermatitis develops after exposure of the workers to sunlight or uitraviolet light.

**Lupinosis** in sheep, cattle and horses. Lupin (Lupinus spp.) cause two distict forms of poisoning in animals.

1. **Lupin or alkaloid poisoning :** Nervous disorder caused by alkaloids present in bitter lupins.
2. **Lupinosis :** It is an ioteric disease (jaundice) caused by a toxin named Hepatotoxin or Icterogen. This is a mycotoxicoses caused by a well known seed borne pathogen of lupin, *Phomopsis leptostromiformis*. Infected pods are more toxic than infected seeds and stalks.

**Factors affecting mycotoxin production**

1.Host factor

2. Pathogen factor

3. Agronomic practices & Environmental factors

1. **Host factor :** Host resistance / susceptibility to the fungi influence the mycotoxin production.

**Increased toxin production :** Higher sugar content and greater seed surface lipid level of the host enhanced the toxin production. Ex. Maize affected with *Aspergillus* spp.

**Decreased toxin production :** Lesser size of the hilum decreased the toxin production. Ex. Resistant varieties of pea nut.

Compactness of sclerotized cells, higher level of lignin and tightness of cells results in decreased chances of the entry of the fungal mycelium. Hence, less toxin production.

**2. Pathogen factors**

**i. Levels of Virulence :**

**ii. Inoculum density :** Quantity of Inoculum

**iii. Reproduction pattern of the Pathogen**

* High birth rate
* Low death rate

**iv. Ecology of the Pathogen**

* Internally seed borne
* Externally seed borne
* Contaminant

**v. Easy & rapid dispersal/Spread of the Pathogen**

**vi. Adaptability of the pathogen :** Pathogen have the capacity to adopt in adverse

conditions.

**3. Agronomic practices & Environmental factors:**

**Planting time :** Late planted maize had a greater chance for pre-harvest Afla-toxin production as compared to early planted ones. Late harvesting of peanut results in an increase in Afla-toxin production

**Soil type :** Mycotoxin production is less in vertisols as compared to the crop grown in alfisols

**Fertilizer levels :** Plant stress associated with reduced fertilization increases the incidence of Afla-toxin. Ex. In maize

**Drought conditions :** Drought conditions reduced the yield and predispose the plants to fungal infection and increases the toxin production

**Damaged pods & kernals :** Cracked or wounded pod wall or seed surface provide the more chances of the fungal entry lead to higher toxin production.

**Insect damage :** Insect damage leads to formation of wounds and provide easy entry to fungal mycelium.

**Competition of mycoflora:** *Aspergillus niger* prevents the infection of *A. flavus* in peanut.

Metabolites of *Neurospora* sp. & *Rhizopus* sp. inhibit the growth of *Aspergillus flavus* in pea nut.

**Moisture content:** Seed/grain moisture content (>12%) increases the chance of infection. Low soil moisture favours the fungal invasion & increase the toxin production

**Temperature :** Warm weather favours the fungal growth & toxin production. Ex. *Aspergillus flavus* infection on maize seeds is favoured by high temp. (32-380C) rather than cool temp. (21-260C)

**Oxygen-CO2 concentration :** With increasing **CO2** concentration, decrease in toxin production. Similarly reduced **O2**  concentration, decrease the toxin production.

**Techniques for the detection of mycotoxins**

During fungal pathogenesis several metabolic compounds are produced that are hazardous to the health. Several analytical methods have been advocated and standarized for the detection of mycotoxins. The accuracy varies from one method to another as well as the type of Agricultural commodity.

* Black light
* Mini column chromatography (MCC)
* High performance liquid chromatography (HPLC)
* Gas liquid chromatography (GLC)
* Thin layer chromatography (TLC)
* Fluorotoxin meter
* ELISA (Enzyme linked immuno sorbant assay)
* Radio-immuno assay

**Management of mycotoxin production**

Basic concept to manage the toxin production seems to provide the conditions that inhibit the growth of toxin producing fungi. Preventive measures includes :

1. Proper seed drying
2. Precautions during handling of produce during harvesting, transit and storage.
3. Appropriate storage conditions particularly RH, temperatue, Oxygen-CO2 concentration, insect and disease free material
4. Cleaning of seed material ( removal of broaken and damaged seeds from seed lot)
5. Physical seed treatment- Hot water, dry heat, aerated steam.
6. Pre-harvest spray of chemicals.
7. Seed treatment with chemicals, natural products, bioagents
8. Biodynamic seed soaks and sprays